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Wild Land Vegetation Resource Inventory

A Remote Sensing Project

Detailed Project Plan for a Joint BLM-NASA-EROS Application Systems Verification Test

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

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WILD LAND VEGETATION RESOURCE INVENTORY

DETAILED PROJECT PLAN

FOR AN

APPLICATIONS SYSTEMS VERIFICATION TEST (ASVT)

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I. INTRODUCTION

It is proposed that a demonstration of the application of remote sensing to the inventory of wild land vegetation be undertaken jointly by the U.S. Department of the Interior (USDI) - Bureau of Land Management (BLM), National Aeronautics and Space Administration (NASA), and the USDI - Earth Resources Observation Systems (EROS) Program. This document describes a detailed project plan for obtaining approval of the terms of the cooperative program.

The Bureau of Land Management is responsible for realty activities on all of the National Resource Lands, the Outer Continental Shelf, and large areas of Federal land under other agency surface management (e.g., National Forests). This area comprises some 474 million acres still in Federal ownership, as well as the publicly owned mineral resources on about 61 million acres of privately owned lands, and the Outer Continental Shelf.

The basic objective of the Bureau is to manage all the resources for which it is responsible and to provide maximum public benefit both currently and in the future with full consideration for good conservation practices and for protection and enhancement of environmental quality. This includes the dedication to carrying out whatever programs are required to insure that the stewardship of the public lands and their resources lead to the optimum planned use for the long range public good.

These programs include activities in the following areas: domestic livestock grazing, fish and wildlife ecology and habitat development, outdoor recreation, timber production, watershed protection, wilderness preservation, minerals development, environmental protection and enhancement, river basin planning, and general land use classification under the concept of multiple use. Resource management and development activities are supported by a construction and maintenance program which provides and maintains roads, trails, and physical improvements such as recreation facilities and watershed control structures; and by an active program to protect the public lands and their resources from wild fires and from all forms of public and private misuse.

To carry out these programs the Bureau has the need to collect and handle large quantities of information. Further, it is clear to the BLM that the fiscal and manpower resources being committed to the gathering and handling of information of all sorts is increasing. This is due to (1) the increasing public awareness of the importance of wild lands as a national resource, (2) recent acts of Congress which have increased the size of the BLM's program and work force, and (3) the increasing need for documentation of the bases of their management actions, including baseline resource conditions, trends, plans, and environmental analysis of proposed actions. For example, a large fraction of the potentially vital energy resources of the nation (e.g., coal and oil shale) underlays Bureau-managed lands; the development of these resources in a manner consistent with public needs will require timely and comprehensive

inventory information.

Within the BLM there have been a number of ad hoc efforts toward the automation of an information system and the use of remote sensing to satisfy some of these information needs. These efforts have not been guided by any Bureau-wide strategy or plan. If a Bureau-wide Remote Sensing Strategy is not adopted soon, there will be great potential for overlap, inefficiencies, and major gaps in the installation of modern automation and remote sensing technology within the BLM's operation. Moreover, these ad hoc efforts may not be at the level or in the direction truly needed to be responsive to the BLM's needs for the future.

During the past year, the BLM was involved in the preparation of a comprehensive, strategic long-range plan. This Strategic Plan would adapt the latest in automatic data processing and remote sensing technologies into a Bureau information system. The Strategic Plan was designed to point the direction in which the BLM might go and to provide a basis for more informed decisions about (1) the acquisition of information-system hardware and software, (2) the automation of system data, and (3) the use of remote sensing technology. This Strategic Plan has now been translated into a "Plan of Action" which is the blueprint for implementation. The initial stages of implementation have begun and steady progress is anticipated.

It is proposed that the BLM, NASA and EROS work together to develop

the remote sensing aspects of this plan; and through an Applications System Verification Test (ASVT) design and demonstrate a system capable of satisfying as many of the BLM's information needs as possible using remote sensing as the primary data source. Among the many BLM information needs in which remote sensing can play a significant role, the broad area of "wild land vegetation inventory" is considered to be very beneficial to the Bureau. The positive results of many experiments sponsored by NASA and EROS using LANDSAT and aircraft data have shown that remote sensing is a potentially important tool for identifying wild land vegetation in any natural resource inventory system.

Indeed, the availability of data acquired by optical mechanical scanners operating in aircraft and spacecraft, and the capability to analyze these data with computers, has added a new dimension to the analysis of remote sensing data. With the launch of NASA's Earth Resource Technology Satellites (LANDSAT 1 and 2) in 1972 and 1975, respectively, carrying multispectral scanners, came the need for improved digital analysis techniques and the development of new procedures for using multispectral scanner data in wild land resource inventory. The Bureau of Land Management, and other organizations (NASA, EROS, Forest Service, etc.) have undertaken programs to investigate how remote sensing techniques which employ digital classification of line scan data and multistage sampling can be applied to wild land vegetation surveys.

Early analysis of aircraft line scan data (in photographic format) demonstrated that classification of vegetation cover in rangeland and forest land environments can be improved by analysis of imagery collected simultaneously in the ultraviolet, visible, near-infrared, and thermal-infrared bands of the electromagnetic spectrum (Carneggie, 1967; Lent, 1968).

Most of the early computer classification of line scan data was performed by the Laboratory for Applications of Remote Sensing (LARS) at Purdue University. These studies focused upon agricultural crops. Crops lend themselves more to computer-aided analysis than wild land vegetation/terrain types because they generally are more uniform in their spectral characteristics. In the literature the accuracy values for digital classification of crop types on aircraft line scan data ranged from 50 to 99 percent. The accuracy values associated with individual crop classification varied considerably as a function of crop type, crop mixture, season of data acquisition, field size, areal extent of classification and methodology for determining classification accuracy. Thus classification accuracy figures must be viewed carefully, since the method of selecting test fields can seriously bias classification results (Colwell, 1972).

In many of the early digital classification studies, classification accuracy figures computed for training fields were used as a measure of overall classification accuracy. Such a method is not statistically valid and generally produces misleading, high accuracy values,

since the training fields are generally chosen because of their size and uniformity. Classification performance on training fields does not reveal the error associated with edge effect pixels, classes of small area and heterogeneous classes. Early digital classification of cover types in wild land environments was performed by Rhode and Olson, (1972) and Wagner and Colwell, (1969) who found that for a few wild land categories classification accuracy was acceptable.

Computer Aided Digital Classification of LANDSAT Digital Data

Over the past decade, tremendous progress has been made in the development of computer-aided analysis techniques involving the application of pattern recognition theory to multispectral scanner data. Much of this progress has been made at the Laboratory for Applications of Remote Sensing (LARS) at Purdue University, Indiana. The basic computer software program called LARSYS (developed at LARS) and/or a modified version thereof is used by most investigators performing digital classification of LANDSAT computer compatible tapes (CCT's). The normal procedures for use of the LARSYS software are as follows (Fleming, Berkebile, and Hoffer, 1975):

1. Define a group of spectral (training) classes.
2. Use a statistical algorithm to calculate statistical parameters of training classes.
3. Use these latter statistics to train a pattern recognition algorithm (train classifier).
4. Classify all data points (pixels) into one of the predetermined training classes.

5. Produce classification results in map and tabular form.

The two most common techniques for defining the training classes are the "supervised" and "unsupervised" approach. The supervised approach assumes that the analyst will select the training fields for the known cover types. The "unsupervised" approach relies on a clustering algorithm to divide a training area (which may contain several cover types) into a specified number of spectral classes. In the latter approach, the analyst must be able to identify the ground cover type that corresponds to the spectral classes defined by the computer.

Most of the literature dealing with computer aided analysis of LANDSAT data use either a supervised or unsupervised approach for training the typical maximum likelihood classifier. In a study by the Aerospace Systems Division of Bendix Corporation in Ann Arbor, Michigan, vegetation covers types in Southwestern Alaska were classified into 15 categories of vegetation. Some examples are: deciduous forest, high brush, alpine tundra, moist tundra, moderate density spruce and hardwood, wet grasses, poplars, and muskeg. The accuracy cited was better than 90 percent (Bendix News, 1975). However communication with Bendix personnel verified that this accuracy figure is based upon the accuracy of classification within the training fields used to train the classifier. Although such high accuracies may be expected for training fields, they may not be valid measures of classification accuracy over the 120,000 square miles

Define:
Level I
Level II
Level III

analyzed in the study.

In contrast, U.S. Forest Service personnel have used digital analysis techniques to classify forest and range cover types in South Dakota and Colorado using LANDSAT data. These studies used an unbiased (hence more valid) random selection method (of pixels) to determine classification accuracy. In the predominantly forested area, overall classification accuracy for level II (USGS Circular 671) categories did not exceed 74 percent (categories include: pine, hardwood, grassland comprised of grazed and ungrazed pasture and cropland, bare soil, and water). Overall classification accuracy within the same forested area for level I land classes was 90 percent (Heller, 1975). Classification accuracy was also judged by comparing ground truth map estimates of area (for each cover class) with LANDSAT estimates of acreages for level II categories. Heller, (1975) concludes that "Estimates of area by individual level II classes were poor." Thus LANDSAT is a level I sensor when used without any supporting data.

In a forested and grassland test site in the Front Range of the Rockies, south of Denver, overall classification accuracies for Region level categories ranged from 68 to 84 percent. The Region level in the U.S. Forest Service Ecoclass Classification Scheme is approximately equivalent to level II in the USGS Classification Scheme (Categories included: grassland, deciduous forest, coniferous forest, barren, and water). In attaining these overall

accuracy figures, grassland and coniferous forest classes were more accurately classified than deciduous forest. When more refined categories were classified, for example, at the Series level (approximately equivalent to level III, USGS Circular 671), overall classification accuracy ranged from 45 to 51 percent (categories included mountain bunchgrass, shortgrass, wet meadow, aspen, ponderosa pine, mixed conifer, lodge pole pine, barren, and water). Acknowledged sources of classification errors were: (a) similar spectral responses between categories, (b) spectral variation within categories, (c) slope and aspect and (d) edge effects between two cover types. In any future project these sources of error would require intensive research to develop techniques for treating them.

Hoffer, et al., (1974), applied a modified clustering (unsupervised) approach to computer-aided digital analysis in a forested environment near Durango, Colorado. Results achieved were similar to the Forest Service study. Hoffer worked with geometrically corrected LANDSAT data, which facilitated the training of the classifier and produced corrected data that were accurate to within one resolution element. However, in the process of correcting the data, approximately three percent of the data points were deleted (Hoffer, 1974; Anuta, 1973). Overall classification accuracy for level I and level II categories was 94.8 and 76.5 percent, respectively. Level II categories included: ponderosa pine, spruce-fir, gambel oak, aspen, pasture, barren, water, and cultivated crops. Hoffer concluded that

"the difficulties of distinguishing individual forest types . . . are due in part to effects of topography, the spatial characteristics of the ERTS-1 scanner system, . . . spectral variability due to differences in slope, aspect, elevation, and density of forest stands." Thus topographic variability must be accounted for, before a computer-aided analysis of individual cover types is practical. Hoffer also examined the effects of the number of spectral bands upon classification accuracy. For level I categories, classification performance for all four bands was 94.8 percent.

> "When the best combination of three wavelength bands were utilized (4, 5, 7) classification accuracy was 94.7 percent and when the best combination of only two wavelength bands was utilized (5, 7), the overall classification performance was 94.2 percent. If fewer wavelength bands can be utilized and reasonably accurate results can be achieved, the procedures become more cost effective."

Kalensky (1974) performed computer-aided analysis of a forested test site in Southeastern Ontario, Canada, using three single date tapes and a multidate LANDSAT tape (comprised of the data from each of the three dates). Overall classification accuracy for the categories of agriculture land, coniferous forest, and deciduous forest varied significantly as a function of the date of imagery. Overall classification accuracies attained for the image dates June 1973, September 1972 and October 1973, were 69, 81 and 67 percent, respectively. Overall classification accuracy for the same categories on the multidate tape was 83 percent. Kalensky concluded that "multidate classification of the ERTS digital images is both practical and promising for thematic mapping of broad land cover classes." The data presented by Kalensky, however, suggest that

most of the information contributing to an accuracy level of 83 percent on the multidate tape originates in the September 1972 tape data. Hence, a data tape selected from an optimum single date may produce most of the information which is otherwise contained in a more costly multidate tape.

Maxwell (1975) has used digital analysis techniques (supervised approach) to classify vegetation cover types and biomass classes in the short grass prairie in Northeastern Colorado. Maxwell uses band ratios from the multispectral scanner (MSS) LANDSAT data and canonical transformations (called multivariate categorical analysis by Bendix Corporation) to improve classification accuracy. By forming two new variables with the ratios Maxwell uses 6 variables (two ratios plus four MSS bands) to train the classifier. Maxwell has found that the ratioed data from bands 7 and 5 is the second most important variable for classifying vegetation types (band 5 is the most important) and the most important variable for classifying biomass types. Maxwell presents classification accuracies for training fields, but not for overall classification of either vegetation or biomass classes, or for the amount of improvement in classification accuracy resulting from the use of the ratioed data.

Vegetation biomass and seasonal range condition studies using digital LANDSAT data have been conducted at Texas A & M University and the University of California at Berkeley. In these studies, ratioed spectral data from MSS bands 7 and 5 (Carneggie and others, 1975) and bands 7 or 6, and 5 (Haas and others, Rouse, et al., 1975)

provide a quantitative indicator of seasonal range conditions. These ratios appear to be sensitive indicators of changes in plant condition throughout the growing season in range environments characterized by a moderate to heavy cover of herbaceous vegetation. Ratioed spectral data can be used to determine the relative difference in production of standing green forage between areas within a region and between years for a given area (Carneggie and others, 1975). Rouse and Haas and others (1975) incorporate ratioed LANDSAT data, precipitation since the last LANDSAT overpass, moisture content of the vegetation and temperature data into "a predictive equation for estimating green biomass to the desired accuracy." Although these approaches do not involve automated computer classification, they do require a minicomputer to extract the MSS spectral data to form the desired ratios. Further research is warranted in this area to determine the reliability and practicality of these methods, and the environment in which these methodologies are applicable.

There has been no definitive test of digital classification in rangeland environments. Investigators at the Forestry Remote Sensing Program, University of California at Berkeley, under contract to the BLM have performed digital classification of vegetation cover types in a Great Basin Sagebrush Association in Northeastern California. An unsupervised approach to developing training statistics was used. Thirty-five spectral clusters were identified and classification completed for nearly a million acres of BLM land in the Susanville District. No attempt was made to verify classification accuracy,

but a qualitative assessment suggests that the "classification procedure correctly delineated and identified major vegetation types such as brush (sagebrush shrub), mountain shrub/juniper, conifer, meadow, rock/bare ground and water where these types dominated the spectral response of individual pixels." Problem areas for this type of classification would be: (1) where vegetation cover types are present in mixes, (2) where vegetation cover is sparse (ground surface characteristics dominate the spectral response) and (3) in arid or semi-arid environments.

Although the remote sensing literature contains numerous publications dealing with the digital analysis of LANDSAT data for vegetation cover mapping in wild land environments, few provide a valid quantitative assessment of classification accuracy and accompanying acreage estimation. For the most part, investigators are using the maximum likelihood classifier and are trending towards the unsupervised approach for training the classifier. A recent article by Fleming, Berkebile, and Hoffer (1975) presents classification data which show that overall classification accuracy was improved significantly when using a "modified clustering" (unsupervised) approach for training the classifier. This test of training approaches was applied on level II categories from a forested area in Colorado.

Classification accuracy appears to vary from environment to environment, and with the level of detail to be classified. Expected

classification accuracy will be relatively lower in environments possessing complex physical and biological components. Moreover, classification accuracy is reduced as the number of classes increases.

In summary too few published papers are available to provide a clear assessment for digital analysis of LANDSAT data. Many factors can be cited to explain problems in classification accuracies. Included are spectral similarity of different cover types, topographic effects, small size of many cover types and edge effects along boundaries between types. More attention must be directed toward developing a statistically valid methodology to determine actual classification accuracy for relatively large areas. In addition, similar methodology must be developed to determine the extent to which digital LANDSAT data can provide valid estimates of the acreage for the vegetation cover types classified. More work is needed to determine the trade-offs between analyzing a single date versus a multidate LANDSAT tape. An improvement can be expected using a multidate tape, but is the increase in classification accuracy significant enough to warrant the increased costs for analysis? Some investigators have looked at: (a) classifiers other than maximum likelihood, (b) canonical transformation of multispectral variables and (c) additional variables, e.g., ratios, as a means for improving classification accuracy. These methodologies show some promise, but not enough quantitative data are available to determine if significant increases in classification accuracy are

attainable. Finally, there is a dearth of literature to assess the effects of preprocessing digital tapes for atmospheric, geometric, line drop and banding corrections upon classification accuracy. Thus, although great strides in discriminant analysis procedures have been made in recent years, many serious problems still exist which require careful, in-depth research.

Multistage Sampling Procedures

The term "multistage" in remote sensing literature has frequently referred to several levels from which remote sensing data acquisition has been performed over the same area; for example, low level aircraft, high altitude aircraft and spacecraft. However, the terminology "multistage variable probability sampling" refers to a specific set of statistical procedures (sometimes called multistage sampling) which employ various levels of remote sensing data to make measurements or estimates of a resource parameter from sampling units which are combined to produce a regional estimate of that parameter (e.g., timber volume, acreage, forage production). Because resource managers require cost effective and accurate data regarding timber volume, forage production, acreage, etc., "multistage sampling" techniques must be carefully considered as a potential remote sensing tool for providing needed resource inventory data. The first application of "multistage sampling" procedures to use spacecraft data was by Langley (1971). Timber volume estimates for a five million acre area in Louisiana, Mississippi and Arkansas were made using only ten ground plots, photo interpretation

data from two levels of aircraft photography and one color infrared Apollo 9 space photo. Langley obtained an estimate of 2.225 billion cubic feet (gross) of timber with an estimated sampling error of only 13.0 percent. It was determined that "a 58 percent reduction in the sampling error was directly attributable to the information gleaned from the Apollo 9 photos." Nichols, et al., (1973) used multistage sampling procedures to estimate timber volume within a mixed conifer type on the Plumas National Forest in Northern California.

> "Timber volume estimates were made from three stages: (1) the first stage involved automatic classification of the timberland on ERTS (LANDSAT) data tapes into four timber volume classes. Subsamples, called primary sample units, were selected whose probability of selection in the sample was proportionate to the predicted volume, (2) the second stage was low-altitude photographs where a second timber volume estimate was made by using photo volume tables, (3) the third stage involved selecting individual trees within selected sample photo plots. The trees were then measured for volume on the ground and these volume measurements in turn were expanded (statistically) through the various stages of the sample design to estimate total timber volume over the National Forest Land on a Ranger District of 215,000 acres. The timber volume estimated was 2.44 billion board feet with a sampling error of 8.2 percent. The cost per acre for this inventory was 1.1 cent/acre compared with 25 cents/acre for a conventional inventory."

A direct cost comparison, however, is not appropriate since the multistage sampling procedures derive a regional estimate of timber volume, whereas a conventional timber inventory would collect more detailed data regarding stand structure, species composition and volume by stand type. Langley (1975) also used multistage variable probability sampling to estimate timber volume in a mixed conifer forest of California. A three-stage procedure was used

where estimates were made from the ground and two levels of aerial photographs. The sampling errors estimated for timber volume estimates for individual survey units ranged from 4.6 to 12.8 percent.

As a direct result from applying "multistage sampling" in forest inventory work, researchers at the Univeristy of California at Berkeley Remote Sensing Program modified the procedures used by Nichols in a forest environment to estimate forage production in a rangeland environment. Two Bureau of Land Management planning units (Willow Creek, approximately 310,000 acres and Cal Neva, approximately 640,000 acres) in Northeastern California were the test areas. Sampling units were selected with probability proportional to BLM acreage within each. Estimates of forage production were made from (1) ground measurements, where percent cover by species composition was converted to an estimate of forage production and (2) two levels of aircraft photography, where photo interpreters identified plant communities and assigned a forage production estimate from a table look up list (derived as part of the study). Current forage productivity estimates for Willow Creek and Cal Neva planning units were 17,874 and 50,979 AUM's, respectively (an AUM is the amount of forage required to sustain a cow and a calf for one month). These figures are equivalent to 17.4 acres/AUM and 12.6 acres/AUM respectively for the two planning units. The relative standard error of the estimate was 17.4 and 20.3 percent for Willow Creek and Cal Neva respectively (DeGloria, et al., 1975).

The results from this study must be viewed in light of (a) the assumptions for selecting sample units, (b) the application of the sample design, (c) the methodology for estimating forage production and (d) the possible bias introduced by the productivity estimator. Nevertheless, this multistage sampling study together with those applied in forest environments yield sufficient detail to justify the framework for a quasi-operational project based on a multistage sampling scheme. The Bureau of Land Management will continue to need accurate information regarding forage production, but on a pasture by pasture basis. Thus further refinement of "multistage sampling" procedures are required in dealing with rangelands to determine the contribution of LANDSAT data to a reduction of sampling error and to make the parameter estimates relevant to small management units.

II. OBJECTIVES

During the past several years many factors have caused BLM to move away from its established image of performing the routine work of holding the public land for disposal. That image has been replaced by a more sophisticated management type function of multiple use for the maximum good. As a result BLM has initiated a variety of efforts toward information system automation and use of remote sensing. The distinguishing feature of these actions has been that they were fragmented and did not fit a pattern of any overall strategy or plan. Such an approach had generated overlaps, inefficiencies and gaps in effective information systems management. Consequently BLM developed a "Strategic Plan" for a comprehensive and integrated information systems management program to provide a basis for informed decisions on (1) information systems requirements, (2) data management, (3) use of remote sensing technology and (4) acquisition of information systems hardware and software.

The Strategic Plan proposed to meet BLM needs by providing better data to perform its management function. The plan would automate, or otherwise improve, the Bureau's handling of information that is currently found in lower file drawers, archives, miscellaneous reports and records. This represents an enormous volume of data and information about land. The implemented plan would summarize and categorize this information so that decision makers could obtain

what they need quickly and effectively. In addition, the plan would assist the Bureau in analyzing and comparing data from past trends to present, for similar or dissimilar functions, costs and inputs or outputs. This automated system would also provide an opportunity to assimilate information from other sources, such as remote sensing, and thus expand the capabilities of BLM decision makers.

During the past months the Strategic Plan was translated into a "Plan of Action" which is the blueprint for the implementation of the Strategic Plan. Among other things, the Stragetic Plan provides for the planning and implementation of an operational remote sensing program, training in remote sensing technology and acquisition of certain support equipment. The BLM-NASA-EROS Applications Systems Verification Test (ASVT) is envisioned as a complimentary effort to this already firm Bureau commitment to remote sensing.

The overall objective of this program is to test and demonstrate an automated wild land vegetation inventory system based on remotely sensed data and oriented to BLM State and District Office management requirements. Upon completion of the project, the information gained will allow the Bureau to make an informed decision on what aspects of Remote Sensing Technology the BLM can implement in its operational programs. In addition, the following objective is identified: to bring into the BLM information system management

program to be established in Denver, the remote sensing data processing hardware and software required to process remote sensing data. This is to be accomplished during the initial year of the project so that BLM personnel can begin processing and interpreting earth resource data as early as possible. The goal is to have BLM completely operational at the completion of the program so that techniques developed during the project are carried through into day-to-day management practices. In order to achieve these objectives, the following tasks and types of products have been identified:

1. Vegetative Type Maps. Through a system of stratification and classification, prepare map overlays from LANDSAT and other supporting data which show vegetative communities and their characteristics including: species composition, plant height, litter, percent ground cover, density and/or frequency, age and form class, rocks, crown cover, vigor and bare ground. It is recognized that with current satellite technology, a number of these characteristics can not be determined with LANDSAT data.

   Other map overlays and tabular information which will result from the preparation of the primary vegetative type maps include surface water resources, existing road systems, geologic formations, and data which could be used by other

management programs such as identification of archaeological and scenic zones.

2. Acreage Compilations. Through digital processing quantify by acreages any combination of vegetative communities and their characteristics. Summations will be made by land ownerships and any combination of land units.

3. Production Estimates. Through multistage sampling techniques, develop production estimates for timber and woodland resources, livestock and wildlife forage, browse and other vegetation-dependent programs such as watershed management and fire management. These data will be tabulated in the formats required and will be displayed on map overlays of various scales.

4. Trend Indications. Through remeasurement over time, changes in various characteristics of vegetative communities will be monitored. Schedules will be developed to show when meaningful remeasurements should be made for the different resource management programs.

5. Sampling Methodology. Through statistical methods, a

sampling methodology will be developed which can be used by most vegetative resource disciplines. This will reduce fragmented sampling programs and will allow data to be aggregated for different areas and for different management objectives.

6. Operational System Specifications. Through complete documentation of equipment used, computer programs, analysis techniques, costs, results and cost/benefit analysis, the best type of equipment and computer configurations to produce the products required under the Bureau's operational programs will be determined and recommendations will be made concerning the optimal organizational structure within the Bureau necessary to make the use of remote sensing operational.

7. Transfer of Expertise. Through involvement in all phases of the project, and through hands-on experience with equipment installed at the Denver Service Center, NASA and the EROS Data Center, Bureau personnel will be provided with training and experience in the analysis techniques to be demonstrated in this project. In addition, intensive training programs in basic photo interpretation and advanced remote sensing will be conducted on regular schedules as part of the effort.

8. Research and Development. R&D needs for expansion of the program to meet other management objectives will be determined.

III. JUSTIFICATION

The Bureau of Land Management (BLM) has the responsibility for the management of 474 million acres of what are termed National Resource Lands (NRL) in eleven Western States and Alaska. In addition the Bureau has the responsibility for managing an estimated 500 million acres of the Outer Continental Shelf (OCS). The management of these lands entails decision making with respect to the multiple use of the land.

The management of range resources involves the issuing of something in excess of 20,000 licenses, leases and permits for grazing use of some 150 million acres of National Resource Lands in the Western United States. This effectively authorizes use of almost 12 million animal unit months of forage by 3.5 million cattle and 4.9 million sheep. In addition forage is utilized by wildlife, wild horses and burros, often in competition with domestic livestock.

Rangeland condition is considered to be satisfactory or better on only approximately 28 million acres (17 percent) of the NRL. Thus, 83% of the land is producing less than its potential.

A high level management option will be necessary to stop deterioration and cause substantial improvement and maintenance of the range condition. This course of action is in fact required under the

Natural Resource Defense Council settlement and involves an intensive effort to complete all management plans in the next few years.

Under the administrative management of BLM, exclusive of western Oregon, there are approximately 21 million acres of commercial timberland with 33 billion board feet producing an estimated annual harvest of 220,000 million board feet. In western Oregon there are approximately 2.3 million additional acres containing 50 billion board feet of high yield commercial timberland yielding approximately 1.3 billion board feet of timber per year. Exclusive of western Oregon there are approximately 91 million acres of the woodland types which produce about 79 million board feet per year.

The management of these lands for sustained annual yields has been the Bureau policy. This type of effort requires considerable information on acreages and timber volumes by critical age and production classes. These data must be gathered periodically and yield estimates updated. Much information is required also for transportation planning as well as sale-layout and logging plans.

Rangelands, forest lands and woodlands are also managed for recreation, including fish and wildlife production, camping, sight-seeing, and for watershed. All these uses require specialized data of various types.

The various decisions which must be made are basically dependent upon information regarding the resources supported by the land.

An inventory of each resource is thus a critical factor in the management of the public lands. Some resource inventories can be relatively simple and provide adequate information. On the other hand some must be very complex if they are to provide even a minimum of information. This means that various levels of sophistication and detail in making an inventory are required. The same is true with respect to the analysis and ultimate use in decision making.

In the past eight years BLM has developed a planning system with a systematic approach to the gathering of resource data and their analyses and integration into an overall management plan. Currently, the resource inventory data are consolidated in the Unit Resource Analysis section of the system (at whatever level of detail and accuracy they exist). Envisioned in the BLM Planning System is improvement in the quality and use of resource inventory data. Therefore the demonstration of uses for remote sensing data needed primarily for the planning system and to some degree for environmental impact statements will be conducted at levels commensurate with remote sensing technology. The abilities of BLM personnel to use the data within the framework of local operating conditions will also be considered. The Unit Resource Analysis requirement as described in BLM Manual 1605 furnishes the

basic guidelines for this remote sensing demonstration effort. It should be noted however that a URA does not provide for all the resource inventory information required. For this reason the URA is viewed as a starting point from which to build.

Planning System

The BLM Planning System is designed to permit informed and objective multiple use decisions through the identification and reconciliation of conflicting land and resource uses. The system attempts to insure that land and resource use, development and management plans and program decisions are responsive to public, Congressional, Departmental and Bureau objectives. The Planning System is an internal management tool, authorized and directed by the Director to help blend diverse authorities and land use opportunities. In addition it is one of the major managerial systems through which the Director, State Directors and District Managers develop and manage the various Bureau Program Activities. These activities are typically related to specific resource or professional disciplines. Each activity has a major mission or purpose for which objectives and standards are specified. The established Program Activities are: Lands, Minerals, Recreation, Wildlife, Watershed, Forestry and Range.

The entire planning system is subdivided into two major sub-processes which operate in coordination. These are Land Use and Development Planning which is the process of planning, under current policy

guidelines, assumptions and constraints, how a given area of land and its resources should be used, managed and developed. Such plans are formulated at two levels: the first of these is the Management Framework Plan which is prepared for a Planning Unit to reconcile major land and resource use conflicts and to apply direction, objectives and constraints for each resource and Program Activity within a specific geographic area. The second level of planning is achieved through a Program Activity Plan which is prepared for each individual resource unit to lay out the manner in which each activity will achieve the objectives and constraints shown in the Management Framework Plan.

The Management Framework Plan and Activity Plan are sufficiently specific in terms of defined land areas, actions planned and the required action sequence to guide on-going management and development actions. These plans do not contain specific cost estimates and calendar type schedules since this detail is added during the program planning phase. The planning horizon is as far as can be visualized into the future but is not precise. On the other hand program planning involves assembling information on potential program costs, estimated results, needs and alternatives and reaching decisions on desired short and long term program goals. Potential programs are based upon and constrained by the land use and development plans set forth through the planning process. Program plans are specific for identified organizational units in terms of calendar years, dollars, man-months, units of accomplishment and have specific short and long range planning horizons.

The BLM planning system was designed to serve three major purposes; direction, information, decision. The basic operation of the Planning System prescribes specific time sequences for both land use and development planning and for program planning. In addition this planning occurs in a careful and orderly manner which allows for input at many levels.

Multiple Use Management

The BLM is committed by law to a program of multiple use of the public lands. This requires a careful combination of uses and activities on the same land area to best serve the public. This is achieved by advanced planning and orderly program accomplishment. There are three main features of the planning process (direction, information, decision) which are incorporated with the action and evaluation features of the Bureau's operations. Direction provides the general goals for the public lands. These are set by the Congress, the President and the Secretary of Interior and are expressed in laws, executive orders, regulations and other documents. From these the BLM establishes objectives and standards for specific program activities and land areas, and criteria for resolving land use conflicts.

Information furnishes data required to develop goals and translate them into actions. Using basic resource inventories a Unit Resource Analysis is prepared covering all resources existing in individual

planning units. Planning decisions are made for specific areas of land so that the unique characteristics of each land area are fully considered. Therefore, a Management Framework Plan is prepared indicating generally what is to be done with each resource within each planning unit. With the Management Framework Plan as a guide, more detailed action and development plans are prepared for each activity.

Incorporated with the above features are activity plans which are translated into action programs through the appropriation system. This is a rather complex process that involves the Department, OMB and Congress. This is the point where the Bureau's program becomes very specific to the many users and interests involved. Finally an evaluation of actions taken is an important part of the total process. The Bureau reviews its programs against its stated objectives and modifies plans and future programs accordingly.

Unit Resource Analysis

The Unit Resource Analysis (URA) is designed to provide a comprehensive analysis of inventory data, resource problems, conditions, uses, production, quality, capabilities and management potential for use in preparing a Management Framework Plan (MFP). In addition it supplies resource information pertinent to land use decisions on a unit and for use in all other phases of resource management. It also provides a means of achieving continuity in resource data

retention and maintenance. A URA is limited to data on air, water, physical land, animal, vegetal and mineral resources and their use. It is not intended to be an original inventory for any resource but is based upon existing resource inventories prepared for their own natural units (watershed, wildlife, etc.). The data for these units are analyzed and recorded for a common geographic base (the planning unit) as a URA. In order to have a comparable data base for all resources, it may be necessary to obtain additional basic inventory data. Frequently it is also necessary to obtain "critical" resource data after initiating work on a URA. Such efforts are limited to filling important inventory gaps. Inventory data are not limited to written data sources. The URA is not a plan of action and does not include decisions to implement specific resource actions. The preparation of the URA involves the examination of all available data and its translation into a common format for all resources. Included is the determination of the present situation and management opportunities.

In order to develop the best multiple use decisions in the MFP it is essential to know the fullest possible potential or opportunity for each resource, <u>without</u> multiple use and economic or environmental constraints. Consequently each resource is studied to a depth constrained only by technological feasibility. Each resource section is prepared in this manner by a resource specialist.

Strategic Plan and Detailed Requirements Definition

The BLM Strategic Plan is a series of tasks which must be executed in a predefined and coordinated manner in order to successfully integrate information systems and information systems management into Bureau day-to-day operations. The Strategic Plan identified several (15) application packages which represent groupings of the Bureau's work. These groupings facilitate implementation by permitting work to proceed within manageable units. Under the Strategic Plan concept the packages will be implemented in four phases. The first of these phases addresses the Bureau resource inventory and URA requirements. The initial work in implementing each phase requires a Detailed Requirements Definition (DRD).

The purpose of the Phase I DRD is to define a data base, its use and maintenance, related to resource inventory and Unit Resource Analysis which will assist all personnel who use those data. The Bureau has charged a team of specialists with this effort. This team will define data and process requirements within the framework of current BLM policies and procedures. Where no procedure exists or where the team feels it is inadequate, the situation will be documented and referred to the appropriate staff for necessary changes. The Phase I DRD is limited to information requirements relating to the applications involving resource inventory and Unit Resource Analysis. Requirements more reasonably fulfilled within another application area are put aside. A set of guidelines were developed by the appropriate committee and staff prior to

the beginning of the DRD effort to answer the question, "Does the requirement being discussed belong in this DRD effort or would it more reasonably be supported within a later effort?" This scope limitation is necessary in order to divide the total Bureau requirements definition activity into groups of Bureau functions that are manageable for detailed analysis.

Interface requirements from other application areas will not be ignored. They will be integrated into the current DRD effort as applicable. It is not required or expected that the DRD team will define all requirements or interrelationships in the initial phase. However the state of data base management technology allows the users to expand and change requirements on an evolutionary basis independent of application areas that may relate to those data. It is within the scope of the initial DRD for appropriate field personnel to identify requirements and interrelationships to be included in the DRD to insure that basic and critical requirements and relationships are defined and developed. In line with these principles and policies the data to be put into the system will be handled in the same way. Where existing data are not adequate to fulfill the identified requirements, they will be used to the extent that they can fulfill some of the requirements. Additional or improved data will then be collected in the normal course of business and the data banks updated as necessary.

It is recognized that the DRD could have a significant impact

upon the scope of this project. As the DRD effort evolves in the coming months it will be closely monitored so that new requirements can be incorporated into this project plan. However since the ASVT effort has been designed to use the URA as a starting point, it is felt that generally speaking the elements defined in this plan will be complimentary to the DRD effort.

Susanville Project

During the past two years the BLM funded a study to demonstrate at the local, state and national levels the application of remote sensing techniques for acquiring multidisciplinary resource information. The study was conducted in the BLM Susanville District which is located in northeastern California and northwestern Nevada. Although the program was concerned with remote sensing in its most general terms, a number of specific applications of LANDSAT technology were investigated. Among these were: (1) the manual analysis of LANDSAT imagery to map broad landscape-vegetation resources; (2) the manual analysis of seasonal multidate LANDSAT imagery to demonstrate the monitoring capabilities of the satellite; (3) discriminant analysis of LANDSAT digital data to produce vegetation/cover type maps and acreage estimates; (4) automatic analysis of multidate LANDSAT digital data to demonstrate change detection; (5) the application of multistage sampling procedures to provide estimates of productivity.

An analysis of the output products from this study concluded that

certain information extracted from satellite data and supported with other stages of data could be used in the preparation of a URA. It was recognized in this study that remote sensing in general cannot provide all of the information required to prepare a URA.

The basic information required by BLM resource specialists and area managers is used for: (1) preparing a URA for each planning unit, (2) preparing a MFP, and (3) Activity Planning. For the URA only broad resource information is required but the other activities need more detailed data. Figures III-1 through 4 lists the types of information, and its source, required by selected BLM resource specialists. The major input to this table came from BLM personnel in the Susanville District. Input from other sources was limited to an evaluation of current state-of-the-art remote sensing technology as a data source. The data source evaluations were also done by Bureau personnel from Susanville. These resource specialists were supplied with 1:125,000 scale LANDSAT imagery, enlarged 1:120,000 scale color infrared photography, enlarged 1:31,680 color infrared photography and resource type maps compiled from manual interpretation and field survey. They were asked to study the level of detail present on each information source and make a judgement regarding its usefulness for selected resource information needs. The information contained in these Figures suggests that some of the information desired by BLM resource personnel can be provided through a combination of field surveys and analysis of some form of remote

RESOURCE INFORMATION REQUIREMENTS FOR BLM RANGE INVENTORY NEEDS

Information Required	Use	LANDSAT	Small Scale	Medium Scale	Conventional	Other	Ground
Vegetation Type	URA/MFP	DA	M				x
Condition	URA	DA/MA		MA/M		LSC	x
Trend	URA					VLSC	x
Forage Production	URA	MA		MA		VLSC/LSC	x
Ground Cover Class	URA/MFP					VLSC	x
Forage Utilization	URA					VLSC	x
Meadow Location	URA	DA	M	M			
Treatment Areas	URA/MFP		M	M			x
Fence Line Location	URA				M		

Analysis Mode: Manual (M); Discriminant Analysis (DA); Multistage Approach (MA)
LSC - Large Scale Color - 1:1,000 or smaller
VLSC - Very Large Scale Color - 1:1,000 or larger
Small Scale - 1:120,000 - Color Infrared
Medium Scale - 1:30,000 - Color Infrared
Conventional - 1:15,840 - Black and White

Figure III - 1

RESOURCE INFORMATION REQUIREMENTS FOR BLM FOREST INVENTORY NEEDS

Information Required	Use	LANDSAT	Small Scale	Medium Scale	Conventional	Other	Ground
Forest Cover Type	AP/URA/MFP	DA,MA	M	M		CIR@1:12,000	x
Timber Volume	URA/MFP	MA		M,MA		LSC	x
Stand Age and Site	URA			M			x
Timber Mortality			M	M	M		
Reforestation Potential	URA			M			
Plantation Monitoring						LSC/CIR	
Site Index	URA					Ground Survey	x
Road Network and Trails	URA		M	M	M		
Sensitive Areas	URA			M			

Analysis Mode: Manual (M); Discriminant Analysis (DA); Multistage Approach (MA)
LSC - Large Scale Color - 1:1,000 or smaller
VLSC - Very Large Scale Color - 1:1,000 or larger
Small Scale - 1:120,000 - Color Infrared
Medium Scale - 1:30,000 - Color Infrared
Conventional - 1:15,840 - Black and White

Figure III - 2

RESOURCE INFORMATION REQUIREMENTS FOR BLM WATERSHED INVENTORY NEEDS

Information Required	Use	LANDSAT	Small Scale	Medium Scale	Conventional	Other	Ground
Topography, Geology, Landform, Drainage	URA	M	M	M			
Location of Streams	URA/MFP			M			
Location of Lakes, Reservoirs, Ponds		DA		M			
Stream Channel Characteristics						LSC	x
Vegetation and Soil Type	URA					LSC	x
Erosion						LSC	x
Treatments and Improvements				M			
Snow Mapping		M		M			
Water Quality	URA			M		LSC	x

Analysis Mode: Manual (M); Discriminant Analysis (DA); Multistage Approach (MA)
LSC - Large Scale Color - 1:1,000 or smaller
VLSC - Very Large Scale Color - 1:1,000 or larger
Small Scale - 1:120,000 - Color Infrared
Medium Scale - 1:30,000 - Color Infrared
Conventional - 1:15,840 - Black and White

Figure III - 3

RESOURCE INFORMATION REQUIREMENTS FOR BLM WILDLIFE INVENTORY NEEDS

Information Required	Use	LANDSAT	Small Scale	Medium Scale	Conventional	Other	Ground
Habitat Type	URA	DA	M	M		LSC	x
Habitat Condition	MFP	MA		M		LSC	x
Habitat Trend				M			x
Habitat Production		MA		M		LSC	x
Forage Utilization	URA/MFP						x
Deer and Antelope	URA/MFP					Aerial/Visual	x

Analysis Mode: Manual (M); Discriminant Analysis (DA); Multistage Approach (MA)
LSC - Large Scale Color - 1:1,000 or smaller
VLSC - Very Large Scale Color - 1:1,000 or larger
Small Scale - 1:120,000 - Color Infrared
Medium Scale - 1:30,000 - Color Infrared
Conventional - 1:15,840 - Black and White

Figure III - 4

sensing data. Medium scale (1:31,680) color infrared aerial photographs provided sufficient detail to satisfy the greatest number of "information desired" items. This can be attributed to the fact that the resource information derived from these photographs is often detailed enough for Management Framework and Activity Planning, and can be generalized to satisfy the needs for the broader levels of information in a URA. The very small scale color infrared photographs were judged satisfactory for certain broad applications. Many of the broad classes and resource types were mapped satisfactorily from these photographs for URA. BLM personnel from the Susanville District found little use for manual analysis of LANDSAT data. They recognized its value as a monitoring tool for detecting change, but its lack of detail made it of limited use even for broad resource mapping. The optimum use of the LANDSAT system appears to be for providing (1) digital tapes from which discriminant analysis procedures can classify many of the broad resource classes, and (2) the first stage in a multistage sampling procedure which can efficiently estimate productivity and condition of forest, woodland and range resources on a planning unit, district, or regional basis. For most of the resource applications, field surveys are required. Exceptions include those tasks where detecting and documenting conspicuous features such as meadows, springs, reservoirs, etc. are the objective. Prior to the final production of map overlays, field surveys are required to verify the image interpretation and to classify map units. Some ancillary information such as

associated plant species, soil texture, depth, and condition can be acquired only through ground surveys. However, preselection of sampling sites based upon stratification of remote sensing data, makes ground survey work more efficient. Ground sampling for species volume, cover and associated vegetation characteristics is an integral step in applying multistage sampling procedures to estimate resource productivity and condition on a regional basis. Field verification of representative resource types also is prerequisite to training activities accompanying discriminant analysis procedures.

Based on this information, it is obvious that with satellite data by itself relatively few of the BLM inventory needs can be met. On the other hand a number of needs can be addressed using combinations of LANDSAT, larger scale imagery from aircraft and ground observations. For many needs, satellite data offer nothing and these will have to be satisfied with more conventional methods. Figure III-5 lists information needs in the Unit Resource Analysis which, based upon past demonstrations, can be partially obtained through the use of satellite data. To obtain this table the elements of a URA were considered individually against the information and conclusions from the Susanville Study and other research projects. Those elements which could be addressed using LANDSAT were extracted and categorized as either a proven or a possible application. The form or type of analysis required to obtain the information from the imagery was then matched with each element.

BLM INVENTORY REQUIREMENTS VS. LANDSAT CAPABILITY

Unit Resource Analysis Requirement (From BLM Manual 1605)	LANDSAT Capability		Type of Analysis and Support Data
	Proven	Possible	
1605.31 Climate			
Snow Pack	X		LM, LDA
Thunderstorm Pattern		X	LM, LDA
1605.32 Topography			
General Relief Characteristics	X		LM
Mountain Valleys: Orientation and Structures	X		LM
Major Streams and Canyons	X		LM
1605.33 Geology and Soils			
Geology	X		LM, LDA, LSP, ground
Soils	X		LM, LDA, LSP, ground
1605.34 Vegetation			
Major Types and Associations	X		LM, LDA, LSP, ground
1605.35 Water Resources			
Drainage Patterns and Location	X		LM, SSP, MSP, ground
Major Runoff Areas	X		LM, LDA, MSP
Major Lakes, Ponds and Reservoirs	X		LM, LDA, MSP
1605.37 Fire			
Fire Occurence	X		LM, LDA, MSP
Fire Hazard		X	LDA, SSP, ground

Figure III - 5

BLM INVENTORY REQUIREMENTS VS. LANDSAT CAPABILITY (Continued)

Unit Resource Analysis Requirement (From BLM Manual 1605)	LANDSAT Capability		Type of Analysis and Support Data
	Proven	Possible	
1605.38 Limiting Physical Factors			
Earthquake Faultlines	X		LM, LDA
Flood Hazard		X	LM, LDA, MSP
Landslide Hazard		X	LM, MSP
1605.39 Development, Facilities & Service			
Land Treatment		X	LM, LDA, SSP, ground
Major Roads and Airports		X	LM
1605.41 Lands			
Urban and Suburban	X		LM, LDA
Agricultural	X		LM, LDA
Utility Corridors		X	LM, LDA
Public Purpose Areas		X	LM, LDA, MSP
Off Road Vehicle Areas		X	LM, MSP
Stripmines	X		LM, LDA
1605.42 Minerals			
Economic Reserves		X	LM, LDA, SSP
1605.43 Forest Products			
Forest Land Inventory Classification	X		LM, LDA, SSP, MSP, ground
Site Quality		X	LDA, SSP, MSP, ground
Stocking		X	LDA, MSP, LSP, ground
Regional Timber Volume	X		MSS-LDA, MSP, LSP, ground
Woodland (Cover Type, Volume)		X	MSS-LDA, MSP, LSP, ground

Figure III - 5

BLM INVENTORY REQUIREMENTS VS. LANDSAT CAPABILITY (Continued)

Unit Resource Analysis Requirement (From BLM Manual 1605)	LANDSAT Capability		Type of Analysis and Support Data
	Proven	Possible	
1605.44 Range Management			
Range Vegetation Types	X		LDA, SSP, ground
Range Condition by Type		X	LDA, MSP, ground
Range Trend by Type		X	LDA, MSP, VLSC, ground
Acres	X		LDA, MSP, ground
Forage Production	X		MSS-LDA, SSP, LSP, ground
1605.45 Watershed			
Covered under 1605.35			
1605.46 Wildlife Habitat			
Terrestrial Species and Habitat Boundaries		X	LDA, MSP, LSP, ground
Aquatic Species and Habitat Boundaries		X	LDA, MSP, LSP, ground
1605.47 Recreation			
Quality Evaluation Covered under 1605.32 & 1605.34			

LM - LANDSAT Manual
LDA - LANDSAT Discriminant Analysis
MSS - Multistage Sampling
SSP - Small Scale Photography (Color Infrared)
MSP - Medium Scale Photography (Color Infrared)
LSP - Large Scale Photography (Color)
VLSP - Very Large Scale Photography (Color)
C - Conventional Black and White Photography
ground - Ground Observations

Figure III - 5

IV. TECHNICAL PLAN

A. Analytical Procedures

In order to conduct a wild land vegetation inventory of a resource area covering a large geographic area, multiple remotely sensed data sources are necessary as inputs. These sources include LANDSAT imagery (photographic and digital), U-2 and other aircraft photography at various scales, tied to ground truth obtained through systematic ground sampling. Discriminant analysis techniques are often applied to LANDSAT multispectral scanner (MSS) digital data to produce in place maps of vegetative communities or classes, representing broad aggregates of plant species, soil type, and geomorphology.

Discriminant Analysis is not limited exclusively to mapping discrete parameters, such as, cover type. In other applications continuous parameters, such as, timber volume, percent cover, and production (biomass) are mapped. The class ranges are selected to maximize separability. The discriminant analysis generated in place maps together with the aerial photographs and ground sampling all serve as inputs into a multistage sampling framework for the purpose of compiling quantitative estimates of such parameters as, productivity for timber or range over aggregate areal allotments.

Digital data from the LANDSAT MSS available from the EROS Data

Center (EDC), Sioux Falls, South Dakota on computer compatible tapes (CCT's) is the primary data input. A set of CCT tapes provides data for one LANDSAT scene (approximately 115 x 115 statute miles). Complete coverage of an area may require mosaicking imagery from multiple scenes and multiple dates. These CCT tapes, as preprocessed by the Goddard Space Flight Center (GSFC), contain line length corrected data for the four MSS channels. Aerial photography with supporting ground sampling is necessary for the identification and selection of training sets. Supplemental aerial photography and supporting ground sampling are also required for verification of the discriminant analysis classification results. To minimize biasing the verification in a statistical sense, these two sets should ideally be independent and non-overlapping.

In a Multistage Sampling scheme, the in place vegetative classification map generated by discriminant analysis is the first information source. Subsequent sampling stages use U-2 photography in one or more scales and ground sampling. The U-2 imagery is often eliminated in forestry applications. The scale or scales of low altitude aircraft imagery needed are environmentally dependent. Commercial high altitude aircraft photographs will be used instead of U-2 when the system is operational.

Discriminant Analysis

In the initial stages of discriminant analysis a series of operations are carried out on the original data from the MSS sensors to correct

sensor problems, to place the data in the format desired for analysis, and to combine, transform or enhance it so that the particular analysis technique to be used can make optimum use of the data. This is called preprocessing.

The first decision to be made prior to performing the discriminant analysis is a determination of the appropriate date or dates of MSS imagery to be used in classification. This decision is influenced by such practical considerations as cloud free coverage dates, and environmentally or ecologically dependent considerations - the resolvability of different plant communities is often time dependent because of phenological factors. Depending on the areal allotment to be examined, it may be necessary to mosaic adjacent LANDSAT scenes to get the desired contiguous coverage. This is often followed by a reformatting of the LANDSAT data on the CCT tapes in order to facilitate further processing.

The second preprocessing phase involves correcting the MSS data for inherent biases, gaps, and inconsistencies in the data base. Two forms of error obvious in any display of the raw data are line drop and banding. Line drop occurs when a MSS scan line has not been transmitted. Data can be artificially constructed from neighboring picture elements (pixels) to correct for this deficiency. Banding is caused by sensor miscalibration and is evidenced in the imagery by striping in the raw MSS data. Again, a cosmetic correction can be performed to eliminate this noise by normalizing

the average response over the entire scene of each of the six sensors to a common base. Spatial resolution errors caused by satellite attitude (roll, pitch and yaw), velocity, altitude, detector sampling delay, panoramic distortion, skew, perspective geometry and sensor mirror scan speed variability can also be corrected using a knowledge of the physical hardware. Electronic filtering to correct for system noise (bias and gain) in the sensor response can be done simplistically using weighted average methods. More sophisticated Fourier methods can be employed but they require considerably more computer time. Contrast stretching is generally employed for image enhancement.

Geometric corrections are available to register the satellite imagery to the ground to minimize location errors. Computationally, it is cheaper to perform geometric corrections after classification as less computer time is involved. Often, this is practical as areas of several pixels of a relatively homogeneous nature are used as training sites and are easily located on misregistered imagery. Ultimately, the value of geometric correction prior to training is dependent upon the complexity of the ecological community to be classified.

Geometric corrections can be divided into two types. Open loop corrections using no ground control points account for scaling and skew in the scanner imagery. The most common method of correction is a nearest neighbor algorithm, although quadratic and cubic

convolution methods are used. The convolution methods take significantly more computation time. For most applications, the nearest neighbor algorithm is completely adequate as the resulting map has a locational accuracy of plus or minus one pixel. Closed loop or fine geometric corrections stretch the imagery to fit known ground control points identifiable on the imagery. Land unit boundaries can be overlaid on these geometrically corrected maps for stratification purposes. If multidate imagery is used in classification, spatially registered, temporal overlays must be generated.

Atmospheric and solar angle corrections are also required for certain applications. The characteristics of the environment and the nature of the classes to be discriminated are the primary factors defining the need for atmospheric corrections. Methods for solar angle correction within a scene are being developed. Dark object corrections are often undertaken to adjust for diffuse reflectance scattering into the atmospheric path caused by haze and smoke over the imagery area. Atmospheric correction should be performed prior to band ratioing of any pixel's channel response.

Prior to classification, the spectral signature of each of the vegetative communities must be defined. Pixels identified as belonging to each class from interpretation of aerial photography and ground sampling are aggregated. Statistical summarizations of the spectral responses of these pixels provide estimates of

parameters characterizing the spectral signature of a given vegetative class. These statistics (mean, standard deviation, range, etc.) provide the basis for discriminating between classes in the classification phase.

Numerous methods have evolved to select pixels representative of the classes to be discriminated. This process is called training. Supervised training is a method in which vegetative classes, as defined on aerial photography, and the corresponding pixels are located in the MSS imagery to constitute the training data. This training method has pitfalls in that vegetative communities resolvable on the ground or on aerial photography are not necessarily resolvable using satellite data. This often results in misclassifications. Also, the same vegetative type can have several signatures because of soil variation, density difference, slope and aspect. Supervised training often fails to identify these differences.

Unsupervised training allows the computer to define distinct classes. The algorithms which do this are called clustering algorithms. These algorithms require that the number of clusters be defined "a priori." Clustering has drawbacks in that, as the number of pixels to be clustered increases, the computing time and the associated cost increase exponentially. Because of these restrictions, clustering must be limited to small areas, i.e., limited number of pixels.

Combinations of these two approaches have been found to be the most successful and are generally termed modified cluster training, i.e., modified clustering. In modified clustering selected training areas, supported by aerial photography and ground data are delineated on the LANDSAT imagery. The pixels within these areas constitute the training data. Ideally, each of these areas should have no more than a half dozen distinguishable classes. Within these areas, environmental stratification can be performed to separate major ecozones, such as forest and range areas. This stratification minimizes misclassification and maximimizes separability, when different cover types within different strata exhibit similar spectral responses. Within each strata of each training area, spectral classes are generated. Supervised training is used to define spectrally distinct classes, such as water bodies. Spectrally distinct classes for the remaining areas within the training field strata are generated using clustering. Statistics for all the classes generated using the unsupervised and supervised training are calculated for each training area. These statistics can be "cleaned" using histograms and plots of canonical variables to detect erroneous data in the training pixels for each class. These classes are subjected to a separability analysis to determine the redundancy of similar classes from different training areas and to determine the vegetative communities which exhibit spectrally indistinct responses. Various statistical divergence criterion, such as

a Scheffe's procedure*, are applicable here and can be used to quantify the process. Once the redundant and spectrally indistinct classes are identified, these classes are pooled and new training statistics generated.

A test of the representativeness of the classes defined by this process is provided by classifying the selected training area. If maximum likelihood classification is used, probability maps can be generated showing the areas classifiable with a given probabilistic confidence of being correct. If large sections of the training areas are nonclassifiable, it suggests that a spectral class may have been omitted. For this reason, the steps defined above are generally iterative and are repeated until an acceptable probability map is produced.

The final verification of the classes generated by "modified clustering" or any other training procedure is to evaluate the accuracy of the classification of the training areas using the aerial photography and ground data. High percentages of misclassification may indicate that the separability analysis or pooling should be repeated. Through multiple iteration of this process, statistics defining the spectral response of each

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*A Scheffe's procedure is a multivariate statistical method for determining in a multigroup problem if any two groups of observations differ significantly. Each group is assumed to have a multivariate Gaussian distribution with the same covariance matrix (the same assumption used in maximum likelihood classification).

vegetative community class are generated and serve as inputs to the discriminant analysis classifier.

The process of training produces multivariate statistics defining the spectral signature for each of the vegetative community classes to be discriminated. The computing time necessary to perform the discriminant analysis is exponentially related to the number of variates used. In order to minimize the number of variables used in the actual classification, only those variables which enhance signature definition are used.

Two methods are used to optimally reduce the dimensionality prior to classification. The first, stepwise discriminant analysis, sequentially selects those variates from the list of candidates which define the maximum class separability. This selection is done in a stepwise fashion in which, the best variable for class discrimination is selected, the second best variable is selected from those remaining and so forth. In this manner, redundant and non-discriminating variables can be deleted prior to classification.

The second method, canonical variate reduction, is also used to compress the dimensionality of the problem. In order to do this, a linear orthogonal transformation is applied to the original variates to generate canonical variates which are mutually orthogonal or independent. These variates have added utility in that rotational transformation produces variables which define those

dimensions which maximize the between class variation or separation. Since those variates with the largest eigenvalues define the axes of greatest class separation, examination of the eigenvalues associated with these canonical variables allows the selection of the best canonical variates for discrimination. Various methods, all basically subjective, are used to determine which variables do indeed have negligible information value. Criteria, such as using the first four variables selected by stepwise discriminant analysis or deleting those canonical variates with eigenvalues less than unity after implementing a canonical transformation, are advocated.

Following the information compaction process comes classification. Two basic classifiers are presently used in production oriented systems: a gating classifier and a maximum likelihood classifier. Gating classifiers place upper and lower bounds on each variable for each class. This defines bounds on the spectral response for each class. The ranges must not be overlapping or redundant classes and misclassification will occur. Gating classifiers fail to take into consideration the correlations or relational structures of variables within a given class in classification. As a result, in complicated ecosystems, where the spectral resolvability of ecotypes can be difficult, the gating classifier may be inadequate.

In order to achieve satisfactory results most production oriented systems use the maximum likelihood classifier. Spectral classes

are defined by their mean vector and variance - covariance matrix. Under the assumption that each class has a multivariate Gaussian distribution, a maximum likelihood algorithm can classify each individual pixel and generate a probability estimating the correctness of the classification. The Gaussian distributional assumption is not really restrictive because of the robustness of the statistical theory to this assumption.

After classification, a statistically valid or unbiased evaluation of the accuracy of classification should be undertaken. The evaluation of the viability of in place maps produced through discriminant analysis of digital data has been inhibited by a lack of "a posteriori" verification in many studies. Verification provides an index as to the utility of the output product. This verification should be done through some form of systematic or random selection of pixels from each class on the LANDSAT imagery. These pixels can then be compared to classifications based on photo interpreted plots and ground sampling to determine percent misclassified. This statistical sampling design must take into account spatial errors due to pixel misregistration and the realities of collecting photography and ground data for verification purposes. Verification requires additional aircraft imagery and ground truth beyond that obtained for the training phase.

In place maps of vegetative community classes are the primary output of the discriminant analysis of LANDSAT MSS digital data.

A 1:24,000 scale map, suited to overlay a 7 1/2 minute topographic map can be produced on a computer line printer (color coded displays are possible by changing printer ribbons). The discriminant analysis classification results can be stored on computer tape and later become input into one of the currently marketed instruments which generate color coded or grey scale maps through multiple exposure photographic reproduction techniques. Jurisdictional or stratification boundaries can simultaneously be overlayed on any of these hard copy outputs. For each vegetative community class, acreage compilations are obtainable for areas within the jurisdictional boundaries or strata defined on overlays.

A number of production oriented systems have been designed to perform the discriminant analysis functions described above. Each system varies in its preprocessing capabilities, training procedures, classification algorithm, and hard copy output products. The General Electric Image 100 system uses a gating classifier. Purdue University's LARSYS, Environmental Research Institute of Michigan's (ERIM) MIDAS, Electromagnetic Systems Laboratory's (ESL) IDIMS, University of California at Berkeley's CALSCAN, and Colorado State University's LANDSAT Mapping System (LMS) are all configured around maximum likelihood classifiers. The Bendix M-DAS also uses a maximum likelihood classifier but employs a unique algorithm in which only canonical variables are used in classification. The above list is by no means all inclusive since the development and improvement of systems for processing LANDSAT MSS digital data is a continually evolving field.

The term Multistage Sampling refers to a multi-level sequential statistical sampling procedure where the levels correspond to various levels of remotely sensed data, such as LANDSAT MSS, high altitude and low altitude aircraft and ground data. The statistical design is tailored to tie these multiple inputs together to estimate a resource parameter like productivity, over areal allotments or aggregates of interest to the resource manager.

In a multistage sampling scheme, one of the first steps is to define the sampling frame. This frame is a list of non-overlapping collections of elements on which measurements are taken. In the case of estimating resource parameters, this encompasses defining the areal allotments for which estimates of the parameters are needed and delineating the sampling units themselves within each of the allotments. This can be done by overlaying jurisdictional boundaries, such as, planning unit or allotment boundaries, on LANDSAT discriminant analysis in place maps. The environmental strata of interest in forested areas or rangelands can then be delineated using the results of the discriminant analysis on the in place maps or aerial photographs. Within the strata of interest primary sampling units (PSU's) can then be defined. For example, using this approach in a timber volume inventory, PSU's would be selected only from forested areas.

The size of the PSU's, the number of levels of subsequent subsampling, and the size of the sampling units at each of these levels

is a function on the following factors: (1) the practical area covered in one aircraft flight line, (2) the travel time between field check points where ground data collection is performed, (3) the variation between sampling units and (4) the ability to locate sampling units on the next higher scale of photography. In most applications, the PSU's are defined on LANDSAT imagery. Using the discriminant analysis in place map, estimates of the resource parameter, e.g., productivity, can be made for each PSU. The discriminant analysis classes in a forest productivity study may be timber volume classes, while in a rangeland study, the classes may be vegetative types which can be correlated with productivities. This information is used to select subsamples of the PSU's with probability proportional to estimated size (p.p.e.s.). This subsample is flown with large scale photography. The scale is determined by such factors as, the ability to accurately locate the large scale imagery on the LANDSAT frame, and the degree of resolution of the resource parameter inherent in the larger scale imagery. The p.p.e.s. sampling is used to maximize the probability of sampling those units with highest values of the resource parameter, e.g., productivity. If the correlation between estimated size (productivity) and the resource parameter being estimated is high, the error of the estimate over the entire areal allotment is minimized.

This process of sampling can be repeated. The PSU's can be subdivided in secondary sampling units (SSU's) and sampled p.p.e.s.

with larger scale photography. The number of levels of sampling is a function of the correlation between the resource parameter estimates at each level, that is, if the correlations are high, few sampling stages are necessary. The number of sampling units selected at each level is a function of the between unit variability. The final stage in the sampling procedure in any case must ultimately be the ground. On the ground, transects are placed to determine species composition with implied cover type productivities for rangelands or timber volumes in board feet mensurated for forest lands. On the aerial photographs vegetative communities and cover types are interpretable in rangelands and tree heights and crown closures are measured. Both can be correlated with productivity in terms of animal unit months (AUM's) or timber volume respectively. On the LANDSAT in place maps vegetative community classes or timber volume classes are the discriminant analysis outputs.

These data are all used in the multistage estimation process. Photo or ground measurements are used to estimate productivity for the smallest sampling units. In some cases, the ground data are used to calibrate the lowest level of photo interpretation through what is termed double sampling. These estimates are multiplied by the inverse of the estimated proportional size (productivity) to derive resource parameter estimates for the next higher state sampling units. This is carried ultimately to resource parameter estimates for each PSU sampled. The final

stage involves computing parameter estimates for each areal unit allotment. This is accomplished by multiplying each PSU resource parameter estimate by the inverse of the estimated proportional size for that PSU (derived from the acreage compilations of the LANDSAT discriminant analysis classes) and averaging over the PSU's sampled in each areal allotment. In this manner, areal estimates of resource parameters are calculated for each areal allotment, each PSU, each SSU, etc. The primary data output most useful to the resource manager is the resource parameter estimate with its associated estimated error aggregated over the predetermined areal extent.

Currently, at least two groups are using multistage sampling in a production oriented mode. The University of California at Berkeley's Remote Sensing Research Program has used this approach to estimate timber volumes in the Plumas National Forest, California and in various areas in the southeast United States. In addition they have applied multistage sampling techniques to determine range productivity in the BLM Susanville District, California. ESL Incorporated of Sunnyvale, California is applying the same technology to estimate timber volumes in the Pacific Northwest for the Pacific Northwest Regional Commission under contract to NASA/Ames Research Center.

Research and Development

A truly dynamic system must be capable of adapting to accept change as the state-of-the-art advances. Any system for processing LANDSAT

MSS digital data using discriminant analysis should be a dynamic process receptive to advances in technology. The majority of the problem areas currently being researched or needing research are in the development of techniques to improve the discrimination between vegetative cover classes within different ecotypes. For example the effects of slope and aspect on the spectral signatures of different cover types are currently being examined primarily in forested, mountainous terrain. Similarly the effects of solar angle adjustments and atmospheric corrections as they relate to classification accuracy are being examined. Theoretically, adjusting for or removing error sources should increase classification accuracies. At the same time, the cost effectiveness of these corrections should be examined through the relative impact on classification accuracy in different environments. One approach to this problem has been the development of vegetative canopy models and atmospheric models. This work is still in its infancy and has yet to be applied to signature definition in production oriented mapping of LANDSAT digital data. However the value of extending this research is worth exploring.

Very practical work is being undertaken to determine the effects of extension of spectral signatures both spatially and temporally through impacts on classification accuracy. Improvements are being researched for mixed class discrimination in such environments as mixed coniferous and deciduous forest communities. Most of this work has been limited to problem areas encountered within selected environments.

The value of using temporally overlaid digital data for multidate classification in various ecosystems and change detection through the use of temporal overlays should be explored. Critical examination is needed of possible solutions to the difficulties of achieving spatial registration of multidate imagery. Evaluation of the imagery from various dates should be made to determine the most appropriate season for enhanced accuracy in single and multidate classification and change detection. In addition the requirement for performing geometric corrections prior to or after classification, needs evaluation for different ecosystems. One critical question involves the trade-offs between additional computing time required for implementing geometric corrections prior to training and classification versus the possibility of more precise locational accuracy with improved training set location and selection and resultant superior classification accuracy from improved signature definition.

Many general areas of research and development are available which are not necessarily environmentally dependent. Evaluation of the different methods of training to define spectral signatures is needed. Many variations of the modified clustering technique described above are presently in use and merit comparison. Evaluation of the accuracy of different classifier methodologies is also needed. The added value, in terms of classification accuracy, of using canonical variables versus the original variables in classification should be established. The possibilities of implementing Bayesian maximum likelihood classifiers should be explored.

These classifiers employ "a priori" knowledge of a pixel belonging to the various discriminant classes to enhance classification success. In this sense, stratification prior to training and classification, is essentially a crude form of defining "a priori" the likelihood of a pixel belonging to a group of classes.

Multistage sampling methodology has not reached a static state; many questions are yet unanswered. In different environments (e.g., range and forestry) the optimal number of sampling stages have yet to be determined. In addition the optimal sample unit sizes and optimal aerial photo scales at each stage are areas requiring further research. The minimum numbers of sampling units that should be examined at each sampling level is critical in terms of a tolerable error for the estimate. The best variables or resource parameters for estimating proportional size for "p.p.e.s. sampling" merit examination. In range ecosystems best measures of productivity, such as AUM's, are open to scrutiny. The methodologies by which productivity can be estimated from knowledge of the cover type or species composition in rangelands should also be developed, as the value of any later results based on these methodologies is only as strong as the underlying assumptions.

B. Equipment

The heart of the data analysis system will be a fully interactive digital image processing system. This system will be capable of processing the digitized LANDSAT multispectral scanner (MSS) imagery.

The system will have a "stand alone" image processing capability and will provide a wide range of digital image processing techniques and capabilities, e.g., geometric and radiometric correction, supervised and unsupervised classification, etc. The hardware and software configurations will be readily expandable for maintaining the system at the state-of-the-art and for meeting unique data requirements. The general system features are:

1. User oriented, interactive system on a minicomputer
2. User oriented language (operating modes and instructions)
3. Expandable library of processing algorithms
4. Label, store and retrieve images
5. Multispectral data processing and classification
6. Color display with cursor
7. Digital mensuration

The basic system hardware configuration is shown in figure IV-1.

The primary input to the remotely sensed data process is the LANDSAT multispectral scanner data on computer compatible tapes (CCT). The LANDSAT MSS data is obtained through the USGS-EROS Data Center (EDC) at Sioux Falls, South Dakota. The data supplied through EDC are normally of excellent quality and dynamic range but contain both radiometeric and geometric errors due to spacecraft stability and earth rotation and curvature effects. In addition the sensors have their own response characteristics such as bias and gain which can cause "banding" or "striping" on the final image if left uncorrected. Figure IV-2 identifies the major geometric and radiometric corrections

BASIC SYSTEM HARDWARE CONFIGURATION

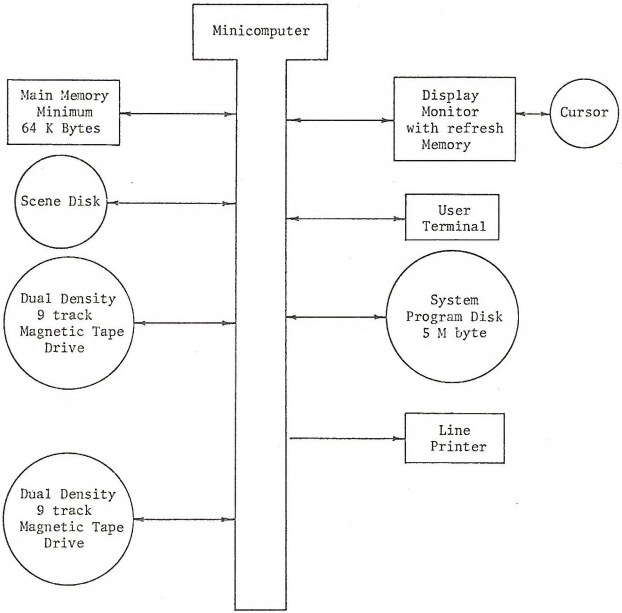

Figure IV - 1

LANDSAT MSS DATA CORRECTION

Geometric Corrections

1. Mirror Scan Velocity Profile
2. Detector Sampling Delay
3. Panoramic Distortion
4. Scan Skew
5. Earth Rotation
6. Spacecraft Velocity
7. Perspective Geometry
8. Attitude (roll, pitch, yaw)
9. Altitude
10. Map Projection

Radiometric Corrections

1. Detector Response (bias and gain)
2. Atmospheric Path Radiance
3. Sun Angle
4. Image Enhancement (contrast stretch)

Figure IV-2

that must be considered as part of the program. At present these geometric and radiometric corrections are not provided by EDC. The software to perform these corrections will be provided as part of the system software package. In the future it is likely that NASA will perform geometric and radiometric corrections as part of the preprocessing of the CCT's at the Goodard Space Flight Center.

The basic interactive digital image processing systems on the market are of the stored program digital computer types. These can be supplemented by hardwired categorical processors or scientific array processors dedicated to the number crunching algorithms that require repetitive computations to process each picture element of the multispectral data. The scientific array processor is a parallel processor in which multiple mathematical operations take place simultaneously, and in a structured manner not requiring program interpretation. Such processors can efficiently process large data arrays through relatively fixed operations at high throughput rates. These specialized processors perform maximum likelihood computations and identify corresponding categories. They output a code for each categorical decision. The advantage of these processors is that they significantly reduce processing time. Such a processor should be considered for a full-scale operational mode, but only after extensive experience has been acquired.

There is available on the market a broad range of digital computers that could be used for digital image processing. The essential question is "what size processor is most appropriate for digital image processing?" Large processors are characterized by long word lengths (36 to 64 bits), large high-speed memories (256K to 2048K words), extensive on line disk memory, a large number of high and slow speed peripherals (tape drives, line printers, card readers and punches), possibly multiple processors and a correspondingly high cost ($3,000,000 and up). Mini-computers on the other hand, typically have shorter word lengths (12 to 32 bits) smaller memories, fewer peripherals, and consequently much lower cost. The circuitry used in relatively small computers is often comparable in speed of operation to that used in large computers. Several trade-offs exist between price and performance of the various computer models. Large scale computers appear to be inefficient in processing the image data using the standard high level languages such as FORTRAN, COBOL, or PL/1 that are normally available on large systems. This inefficiency stems from the small image data word size (7 bits presently and 8 bits for future LANDSAT data). Data arrays typically assign each data value to one full computer word. In a large computer such as the CYBER available to BLM, this results in a 7 bit value being stored in a 64 bit computer word.

A mini-computer with a 16 bit word size is suitable for statistical processing of a moderate number of pixel values. For instance, in

excess of 1,000 LANDSAT pixel values having a mean of 64 can be summed without overflowing a 16 bit word. The mini-computers required in any system that BLM would consider for image processing will have double word arithmetic capability for efficiently handling 32 bit operands.* It thus appears that the word size of mini-computers are better suited for digital image processing than those of medium and large scale computers.

The initial hardware and software configuration does not require time-sharing, i.e., multiple image analysts performing independent image analysis functions. However, whatever hardware and software initially delivered must be upward compatible without a major conversion effort once a time-sharing environment is required. Currently available image processing systems use minicomputers having a main memory size of at least 64K bytes. Since the cost of minicomputer memory is but a small portion of the system cost (64K bytes for less than $4,000), it is advisable to start with a 128K byte size memory. The minicomputer should be capable of easily addressing at least up to 256K bytes for ease of future expansion. Several minicomputer models have such an addressing capability, so there is little need to consider larger computers at this point.

The standard operating system software and utilities will reside on disk. The operating system disk is to be physically separate

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*With 32 bit operands, in excess of 67 million pixels having a mean of 64 can be summed without overflow. Four bands of a full LANDSAT scene amounts to 32,572,800 pixel values (2,340 x 3,480 x 4).

from any other disk such as scene disk or color CRT monitor refresh disk. The operating system disk should have a capacity of at least five megabytes.

Although it is possible to operate without a scene disk, it is considered highly desirable and is a firm requirement for the BLM system. The scene disk should be in the form of removable disk packs with either a fixed head or a moving head read/write mechanism. In addition to any disk areas not directly associated with the user such as the VTOC (volume table of contents), etc., enough scene disk to store all four spectral bands for a full LANDSAT scene is required.*

Two dual density 9-track magnetic tape drives are required to read the computer compatible tapes containing the LANDSAT image data and the digitized ground control points for the geometric correction process.** Two drives are required to permit reading data from one drive, processing, and writing results on the second drive. In addition since each LANDSAT scene is contained on two physical reels at 1600 BPI density, the operation of the system would be quite awkward without the availability of a second drive. This

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*In the future it will be required to store two LANDSAT scenes on disc.

**The means by which the ground control points will be entered is through an X/Y digitizer with output to magnetic tape.

would be the case for reading a scene directly to the color CRT monitor or to a scene disk for further processing. The tape drives will be dual density 9-track drives, i.e., capable of reading and writing both 800 BPI (NRZI coding) and 1600 BPI (phase encoded) tapes. The dual density drives will allow operating flexibility in that both old and new LANDSAT tapes may be processed. It is highly desirable for the associated controller to be able to automatically correct single bit errors and detect multiple bit errors. Tape drives which operate at 45 inches per second or better are acceptable.

Output in the form of categorized images on computer compatible tapes is required. The output CCT's provide a storage media between the various stages of processing and an archive of the results of processing. This eliminates the need to start from ground zero in future processing in any geographic area. It is conceivable that such tapes could be used for futher processing on a general purpose computer, however, the intent is to have the remote sensing effort revolve around minicomputer systems developed to perform these highly specialized functions. Should time demonstrate that greater processing capacity is required, the hardwired multivariate categorical processors and scientific array processors previously mentioned can be considered as alternatives to a large mainframe.

A line printer is required for the following:

1. Bar charts or histograms depicting the number of pixels (picture elements) that fall within various ranges of

reflectance for a given training set. This information is used in assigning reflectance ranges to the various phenomena to be categorized.

2. Printouts of a wide assortment of tabular data. Examples include acreage totals per category, forage production estimates, trend indications, percent area tabulation for each group, and categorization accuracy tables.
3. Line printer gray maps of categorized images. A print symbol is assigned to each of the catagories within a scene. Homogenous groupings of any given category thus appear as clusters of a given symbol. Admittedly, the utility of such a product is somewhat limited in that to be useful, it necessitates taping several maps together and perhaps highlighting symbol clusters via colored pencils. However, the product is very useful in that it is fast and bypasses the photographic processes for an intermediate working product.

A high resolution interactive color TV monitor display is a firm requirement. The output from a color CRT monitor is not a final working product, but the display is a necessary system component which provides the image analyst with visual feedback for the evaluation of classification results and test site selection. A color display is needed to aid the eye in distinguishing the point of separation at classification boundaries. This clear boundary distinction is needed for accurate control and placement of the cursor

as it delineates the boundaries. Although a monitor that is refreshed from disk memory is acceptable it is preferable that the device be refreshed from a solid-state device. In addition random access memory (RAM) types are preferable to the shift register types of refresh memory. RAM would allow the manipulation of partial screen images.

A photographic hard copy of the color TV display is a workable product but should not be construed as the final element due to the limited area represented and its limited resolution. The required color monitor associated with the interactive image analysis system will have a resolution of at least 480 lines with each line containing 512 pixels. The mass-produced color TV tube raster has 525 lines per frame in an interlaced manner with 450 to 512 used for the display. The number of lines displayed must be less than the lines per frame due to limits of vertical retrace time. By mixing the intensity of the three color guns at each pixel point it is possible to obtain a wide range of colors. However, the number of colors that can be discerned by the operator is perhaps 8 to 12. An experienced operator could work with perhaps 16.

A more suitable high resolution photographic product can be produced on a drum type film recorder. Such recorders are used to produce black and white (B&W) products as well as B&W separation negatives for color products. Pixel sizes down to 25 microns on a side can be obtained on a 9 x 9 film image, resulting

in an image having a resolution of 9200 lines containing 9200 pixels each. As a minimum the following photographic hard copy products are required:

- Uncategorized LANDSAT MSS data at 1:1,000,000 scale
- Categorized LANDSAT MSS data at 1:1,000,000 scale
- Categorized LANDSAT MSS data at 1:250,000 scale

Larger scales than the above will be required during the course of the project.

The products identified here may be produced in any combination of BLM in-house equipment, shared equipment available from other agencies, commercial contracts, etc. The products, not the process, are the goal. The ultimate combination of methods to produce the products identified will be dictated by budget constraints as well as the required volumes of each product.

C. Training

The keystone of the entire demonstration project is to develop a cadre of resource managers in the BLM who are thoroughly versed in remote sensing technology. Since the Bureau operates on a State and District level the training program will strive to generate a knowledge of this technology throughout these offices. The Bureau is faced daily with problems that can be addressed via remote sensing if only our resource managers have sufficient knowledge of the techniques to be able to apply them. Consequently dissemination of this science into the States and Districts as rapidly and

effectively as possible is required. An in house study conducted by the BLM during late 1975 and early 1976 revealed that the bulk of our resource managers have had little or no training in basic photo interpretation skills. Indeed in eleven (11) Western States 574 persons were listed as needing basic photo interpretation (PI) training.

To meet these needs this program will provide two forms of training:

1. Basic Photo Interpretation.
2. Advanced Remote Sensing.

The basic PI course is designed for a maximum of approximately 25 attendees, while the advanced course will handle on the order of 15. Trainees for the basic course will be State and District level resource managers and the advanced program will be oriented toward Bureau resource and remote sensing specialists. The project team will receive training at both levels. Four courses are planned each year in Basic PI. These courses will provide a rapid means for bringing Bureau resource managers up to a state-of-the-art understanding of remote sensing. The advanced course will allow Bureau specialists to accumulate additional knowledge and procedures into their programs. Figure IV-3 shows the training schedule for the initial year of the project. At the conclusion of the project the BLM will be proficient enough to continue the training program in house.

Basic Photo Interpretation

The Basic Photo Interpretation course will provide BLM resource

FY 1977 ASVT Remote Sensing Data Training

Location	Course	Dates	# Attendees
Denver, CO	Basic P.I.	Nov. 1-5, 1976	15-25
Phoenix, AZ	Basic P.I.	Nov. 8-12, 1976	15-25
Boise, ID	Basic P.I.	May 16-20, 1977	15-25
Optional*	Basic P.I.	May 23-27, 1977	15-25
Sioux Falls, SD	Advanced	Unscheduled	9-15

*Optional course is to be held in Anchorage, Alaska during the first year. Future selections will be tied to physiographic regions and based upon a defined need in that area.

Figure IV-3

managers with a basic understanding of the concepts and principles of photo interpretation, and their applications to inventorying, mapping, and monitoring mineral, soil, water, wildlife and vegetation resources; emphasis will be on key management problems (e.g., strip mining, soil salinity, soil erosion, water quality, habitat assessment, etc.).

The Basic Photo Interpretation training course for BLM personnel is designed to provide each participant with an understanding of the principals for applying the tools of aerial photo interpretation to day-to-day management operations, which include unit resource analysis, management framework planning, area planning, preparing environmental impact statements and updating existing resource information.

The justification for the training course is based upon: (1) the need for rapid update of resource information within the large wild land areas under BLM control, which can be accomplished with the aid of remote sensing technology, (2) the lack of formal training in photo interpretation among BLM employees and a lack of awareness regarding the uses of satellite and high altitude aircraft imagery and (3) the numerous requests, exemplified by the Canon City District, New Mexico State Office, and DSC Division of Standard and Technology, made by BLM personnel for more formal training in photo interpretation and remote sensing.

In 1972, the Director of the Denver Service Center distributed a photo interpretation questionnaire to six State Directors. Twenty-eight out of 29 questionnaires returned from key state and district office personnel showed that in order to meet their requirements, additional training was needed in photo interpretation. In 1976 a questionnaire sent to State and District Offices indicated 574 people still require additional training in photo interpretation.

The immediate goal is to establish a photo interpretation training course which is recognized in the Bureau Training Catalog and offered regularly so that participants can plan in advance to attend. This training will be conducted by qualified BLM personnel. In the short term, the Bureau will solicit assistance from the EROS Data Center, (USGS), for structuring and conducting the photo interpretation training program. The expenses incurred by EROS personnel will be borne by the EROS Program.

The instruction will consist of a mixture of lectures, slide presentations, workshop exercises, homework problems, reading assignments and discussion. The Basic Photo Interpretation training consists of the following elements:

1. Conducted initially by personnel from the EROS Data Center, and turned over to qualified BLM personnel in approximately three years.
2. A four and one-half day training course.

3. Course given one time per year in each of four regions (Phoenix, Arizona; Boise, Idaho; Denver, Colorado; and an optional location*).
4. Train 15 to 25 participants per course.
5. Interpret photographs of a representative area adjacent to location of training course.
6. A standard syllabus (prepared by EROS Data Center personnel) which includes the following:
   a. Definition of terms.
   b. References regarding agencies from which satellite and high altitude aircraft imagery and other types of aerial photos can be obtained.
   c. Basic diagrams showing relationships of geometry, scale and displacement of photo images.
   d. Classroom exercises for computing scale and area.
   e. Classroom stereo exercises.
   f. Instructions for photo interpretation procedures.
   g. Classroom exercise on feature/condition identification using photo image characteristics.
   h. Text regarding factors affecting photo interpretation.
   i. Instructions for preparation of data base overlays (e.g., land form, drainage, vegetation, cultural and surficial geology).

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*The optional location will be tied to a physiographic region and its selection will be based on a defined need for training in that region. For example Alaska in 1977; O&C timber land in Oregon; Coal and oil shale areas in the Great Basin.

j. Examples of standard map format products.

k. Listing of photo interpretation references and analysis equipment.

7. Field trip activities and exercises to include but not limited to:

   a. Scale determination

   b. Area determination

   c. Section corner location

   d. Use of photos as compass

   e. Feature verification

   f. Sampling methodologies

Training Aids

The following training aids are identified for each participant:

1. One 29 x 29 color enlargement (1:250,000) of a LANDSAT scene containing the problem area.
2. Three 9 x 9 LANDSAT CIR of different dates containing the problem area.
3. A stereo triplet of the problem area in CIR.
4. Black and white stereo triplet of the problem area.
5. Written set of classroom lecture and problem materials.

Advanced Remote Sensing

The advanced training course will provide BLM resource and remote sensing specialists with a basic understanding of the concepts and principles of advanced remote sensing analysis techniques, and their application to earth resource surveying and monitoring

problems. In addition each participant will obtain "hands-on" experience using digital machine aided analysis techniques on aircraft and satellite imagery.

The objectives for this course are: (1) to allow selected BLM personnel to keep abreast of the rapid advancements being made in remote sensing technology, (2) to develop a cadre of BLM experts who will be able to transfer remote sensing technology to other units within the Bureau and (3) to assess the advantages and limitations associated with the state-of-the-art of remote sensing.

The advanced remote sensing training course will be given at EROS Data Center, Sioux Falls, South Dakota. The center has a state-of-the-art Data Analysis Laboratory equipped with digital and analog multispectral/multitemporal image analysis equipment. In addition the center has a highly qualified staff of scientists skilled at using hardware/software systems and experienced at training user agencies on how to apply advanced techniques in a timely, accurate and cost-effective manner.

D. Test Sites

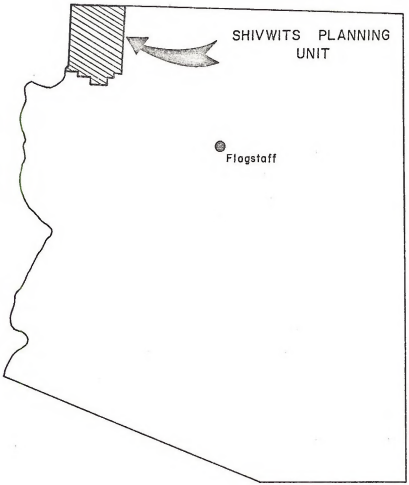
Test sites for this project were selected based upon a variety of criteria. Among these was a requirement that the District contribute five man months to the project. Furthermore, sites that typified the resources found on the National Resource Lands (NRL) under BLM administration were considered. The manner in

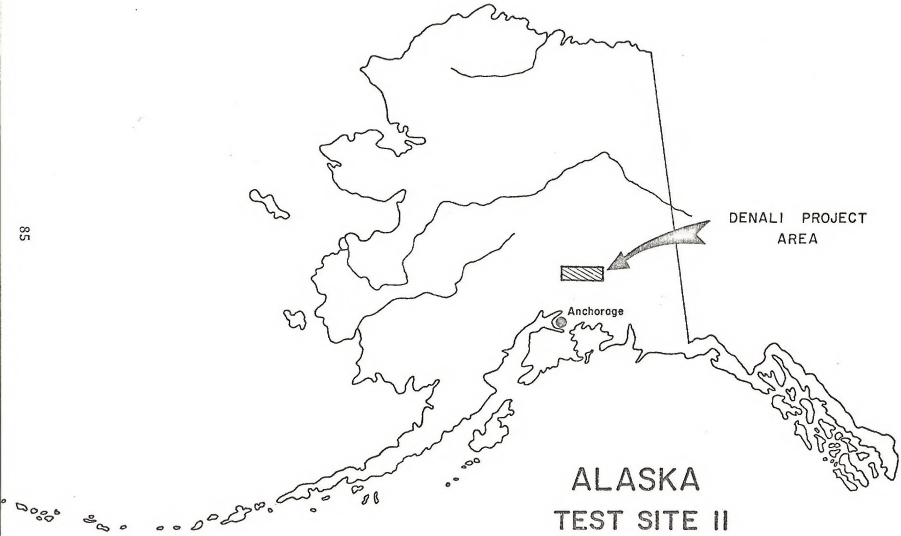
which these lands represented the full spectrum of the NRL and how they would compliment and extend the work from the previous Susanville study was of paramount importance. As a result the following three test sites were identified for this program. Each contains approximately two million acres and represents a complete planning unit. In addition each site possesses a wide range of vegetation types within its association. The test sites are:

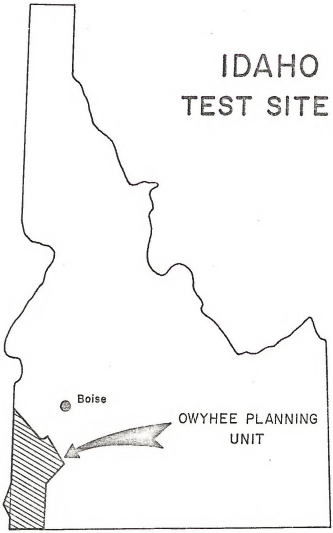
1. Shivwits Planning Unit in the Arizona Strip District which represents the southwest desert community.
2. Denali Planning Unit in the Anchorage District which represents the northern spruce-fir-tundra biome.
3. Owyhee Planning Unit in the Boise District which represents the extensive sage brush-grassland communities of the intermountain area.

Figures IV-4 through IV-6 show the geographic locations of the test sites.

ARIZONA
TEST SITE I




DENALI PROJECT
AREA
Anchorage
ALASKA
TEST SITE II


IDAHO
TEST SITE III
Boise
OWYHEE PLANNING
UNIT

V. Management

This project will be a cooperative effort between USDI-BLM, NASA and USDI-EROS. Major decisions regarding the project will require consent of the three participants.

The contribution of the participating organizations will include the following:

Bureau of Land Management

The BLM will assume responsibility for the overall management of the project, including planning, reporting, and control of functions. BLM will assume the primary leadership for coordination of users, making decisions as to the desired kinds of information which will be acquired under the study, and will provide full-time personnel to carry out these responsibilities. As needed, selected key personnel will be assigned to work with NASA to gain experience and familiarity with the operation of their multispectral classification hardware and with the statistical techniques employed in the data analysis. BLM will be responsible for acquiring large-scale aerial photography and ground truth. BLM will also document the experience of the users and will prepare an independent cost/benefit analysis of the results of the project. The Bureau will provide a project team located in the Bureau's facility at the Denver Service Center. The team will consist of three professionals, one beginning

professional, a training specialist and a secretary. Their expertise will be allocated as follows:

1. Project leader Bonner
2. Biological scientist with specialty in remote sensing Lund
3. Resource specialist (range or forestry)
4. Analyst/system operator (beginning professional)
5. Statistician (biometrician) Garrett
6. Training specialist Wally Crisco
7. Secretary

The Bureau will provide space for the remote sensing data processing equipment to be installed at the Denver Service Center. The final amount and type of this equipment will be determined during the course of the project. The Bureau will also provide office space for the NASA and EROS personnel while they are performing their support roles at the Service Center.

The Bureau will participate in a parallel research and development program with NASA. R&D tasks critical to the project will be identified, scoped and funded through an executive committee (see Figure V-7). As these R&D tasks are evolved to an operational state they will be implemented into the remote sensing system. Figure V-1 is a chart showing BLM resource commitments by project year.

NASA

NASA will assume the responsibility to provide:

BLM RESOURCE REQUIREMENTS (IN THOUSANDS OF DOLLARS) BY PROJECT YEAR AND OPTION

	FY 77 BLM	FY 78 BLM	FY 79 BLM	FY 80 BLM
Personnel	180	180	180	180
Travel	40	35	35	35
Contractor Support	0	0	0	0
Equipment* and Facilities	60	60	30	20
Supplies	10	10	10	10
Training	45	45	45	10
Aircraft Photography	20	20	20	20
Computer Time	0	30	50	50
Data Products	0	0	0	25
Lease-Purchase				
Option 1	0	0	0	50
Option 2	100	155	155	210
Option 3	25	55	55	210
Research and Development				
Option 1	100	100	100	50
Option 2	0	0	0	50
Option 3	50	50	50	50
Total Resources				
Option 1	455	480	470	450
Option 2	455	535	525	610
Option 3	430	485	475	610

*Small Incidental Equipment

Figure V - 1

1. Cooperation with BLM to produce the required output products during the course of the project.
2. Computer systems and remote sensing data analysis facilities until the BLM facilities are on line and operational.
3. Documentation of all NASA furnished software and data analysis techniques necessary for the demonstration.
4. Cooperation with EROS to provide training for key BLM personnel.
5. System analysis of the interface between the remote sensing system and the BLM information management system.
6. U-2 photography (2 copies) at scales of 1:31,680 and 1:120,000 in color infrared (CIR).
7. Appropriate support, depending on the option (see below), for the lease and/or purchase of remote sensing system hardware to become part of the on-site system at the Denver Service Center.

Figure V-2 shows the NASA resource requirements by fiscal year. Figures V-1 and V-2 present a series of three options from which the BLM and NASA can negotiate. All options are considered viable. The intent of these options is to place the necessary equipment for the demonstration at the Bureau's Denver Service Center where resource personnel can become familiar with it. The options also present alternative means of financing needed research and development as a parallel effort to the program. Since R&D is seen as a parallel, complimentary effort to the operational aspects of the program,

NASA RESOURCE REQUIREMENTS (IN THOUSANDS OF DOLLARS) BY PROJECT YEAR

	FY 77	FY 78	FY 79	FY 80
Personnel	(120)	(90)	(60)	(0)
Travel	(15)	(10)	(5)	(0)
Contractor Support	150	200	25	0
Equipment* and Facilities	0	0	0	0
Supplies	5	5	5	0
Training	0	0	0	0
Aircraft Photography (U-2)	15	15	15	0
Computer Time	50	20	0	0
Data Products	25	25	25	0
Lease-Purchase Equipment				
Option 1	100	155	265	0
Option 2	0	0	0	0
Option 3	75	100	100	0
Research and Development				
Option 1	50	50	50	0
Option 2	150	150	150	0
Option 3	100	100	100	0
Total Resources				
Option 1	(530) 345	(570) 420	(450) 335	0
Option 2	(530) 245	(515) 265	(285) 70	0
Option 3	(555) 320	(565) 365	(335) 170	0

*Small Incidental Equipment

($) = Project Funds, SR&T, Personnel and Travel

Figure V - 2

R&D funds are not totaled into NASA project resources. Also shown is the trade off represented by the options between acquiring equipment and funding R&D. Figure V-3 gives the salient features of each option. Since the BLM and NASA resource requirements have been identified in this manner it is appropriate that the basic assumptions governing the options be listed. They are:

1. The remote sensing data processing equipment is to be installed at the Denver Service Center (DSC) during the initial project year.
2. NASA will provide funds for contractor support services to begin analysis and processing on the initial test site while equipment is installed at DSC and BLM project team personnel come up to speed.
3. BLM personnel will begin to phase into the operational aspects of the program following equipment installation at DSC and will be completely responsible for these tasks by the end of year two.
4. NASA will phase out of the program in year three.
5. BLM will continue program on an operational basis beginning in year four.
6. BLM operational program will run an estimated $450K per year beginning in year five.
7. Training program will provide training in basic photo interpretation and remote sensing to approximately 125 resource managers per year (375 total for three years).
8. Training program will provide training in advanced remote

LIST OF SALIENT FEATURES OF RESOURCE OPTIONS

Option I

1. NASA purchases equipment in year 3; equipment on lease/purchase in years 1 & 2.
2. R&D shared; BLM 2/3 and NASA 1/3.
3. Least expensive option for BLM.
4. Most expensive option for NASA.

Option II

1. BLM purchases equipment in year 4; equipment on lease in years 1, 2 & 3.
2. R&D totally paid by NASA.
3. Most expensive option for BLM.
4. Least expensive option for NASA.

Option III

1. BLM pays purchase portion and NASA pays lease portion of lease/purchase contract.
2. Equipment on lease in years 1, 2 & 3.
3. R&D shared; BLM 1/3 and NASA 2/3.
4. Intermediate cost option to both organizations.

Figure V - 3

sensing to approximately 15 resource and remote sensing specialists per year (45 total for three years).

9. All options require that BLM will manage the program.

With respect to the rationale in insisting that the team and equipment be located at the Bureau's facility in Denver, several observations can be made. First the Bureau's experience, as well as that of private industry, has shown that the transfer of a new technology cannot occur in a sterile environment. It is extremely important to place the team and equipment at a facility intimately involved with the organizations operations. Secondly, the placing of the operation at such a facility allows the parent organization to come to grips with the technology on a day-to-day basis. Finally by locating the system in the midst of these day-to-day operations both management and personnel can become involved with the new technology on a first hand basis. For these and other reasons the Bureau feels strongly that the equipment must be located at the Denver Service Center (DSC) as early in the program as feasible and that the Bureau must assume management responsibility for the program.

Thus the acceptance of any one of these options will greatly resolve the technology transfer to the BLM in terms with which it can identify. The installation of the remote sensing data processing equipment at the DSC is timely in relation to the overall goals in implementing the Bureau Information System Management Program.

BLM-NASA TOTAL PROJECT RESOURCE REQUIREMENTS BY OPTION AND PROJECT YEAR

Option	FY 77		FY 78		FY 79		FY 80		Total $		1000 Total $
	BLM	NASA	BLM	NASA	BLM	NASA	BLM	NASA	BLM	NASA	
I	455	(530) 345	480	(570) 420	470	(450) 335	450	(0) 0	1855	1550 1100	3405
II	455	(530) 245	535	(515) 265	525	(285) 70	610	(0) 0	2125	1330 580	3455
III	430	(555) 320	485	(565) 365	475	(335) 170	610	(0) 0	2000	1455 855	3455

Figure V - 4

The entire effort will provide accurate, meaningful and timely information that will dovetail with the Detailed Requirements Definitions in the Action Plan. Finally the Bureau will have a means for evaluating the total remote sensing field on a "hands on" basis.

Figure V-4 depicts the total BLM-NASA project resources required by project year and option. In addition it shows the total dollars involved for both agencies.

USDI/EROS

The EROS program will provide discipline specialists to assist in the technical planning of the project, and to participate with BLM personnel in the data analysis activities. EROS will make its facilities available for training and provide qualified instructors for teaching both introductory and advanced remote sensing courses to the project participants. Figure V-5 shows the EROS resource commitment to the project. Figure V-6 provides the training schedule for both the basic and advanced remote sensing courses.

Management Plan

Figure V-7 is an illustration showing the framework of the management plan. The major functions in this plan are discussed in the following paragraphs.

An executive committee will provide major guidance and control

EROS RESOURCE REQUIREMENTS (IN THOUSANDS OF DOLLARS) BY PROJECT YEAR

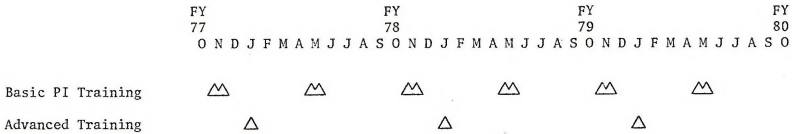
	FY 77	FY 78	FY 79	FY 80
FUNDING*				
Discipline Specialist	5.5	5.5	5.5	0
Basic Training	18.0	18.0	18.0	0
Advanced Training	8.5	8.5	8.5	0
Total Resources	32.0	32.0	32.0	0

MAN POWER				
Discipline Specialist	1 MM	1 MM	1 MM	0
Basic Training	4 MM	4 MM	4 MM	0
Advanced Training	1.5 MM	1.5 MM	1.5 MM	0
Total Man Months	6.5	6.5	6.5	0

*Includes funds for the Man Months

Figure V - 5

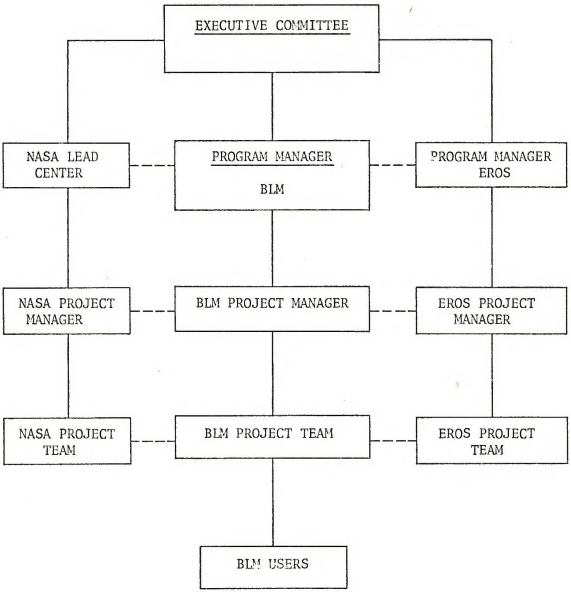
PROPOSED TRAINING SCHEDULE FOR BASIC AND ADVANCED REMOTE SENSING COURSES



NOTE: Training courses are scheduled for November 1-5, 1976 in Denver, CO; November 8-12, 1976 in Phoenix AZ; May 16-20, 1976 in Boise, ID; and May 23-27, 1976 in Anchorage, AK. A similar course schedule is planned for each subsequent project year.

Advanced training will be given to the BLM Project Team in the fall of 1976; Bureau wide courses will be conducted in the late winter of 1977 or early spring of 1978 and at yearly intervals thereafter.

Figure V - 6



———— Line Responsibility

--------- Coordination

Figure V - 7

for the demonstration. This committee will be comprised of one member from each agency. Their responsibilities will include:

1. Formulating and approving policies and plans governing the conduct of the project.
2. Securing resources as agreed upon for the implementation of the project.
3. Approving, within agency guidelines, any major changes in the scope of the project.

SCD ?

A program manager will be appointed by the Bureau and will provide the overall coordination for the project. He will:

1. Present recommendations for major changes to the Executive Committee.
2. Review progress against plans, schedules, and milestones.
3. Provide guidance and assistance in formulating plans and schedules.

Since the Bureau will assume the responsibility for the overall management of the project, it will appoint the project manager. He will report directly to the program manager and he will have the day-to-day responsibility for the operation of the project. He will be located at the Bureau's facility in the Denver Service Center, Denver, Colorado. The project manager will coordinate with the primary users within the test site areas, to assure that they receive the information (products), they have indicated are necessary to assist them in making management decisions. The

project manager will perform the following functions: (1) assure that full-time Bureau and contractor personnel are carrying out the daily work as scheduled; (2) select key personnel within the Bureau to work with NASA and EROS to gain experience with the operation of the hardware and statistical techniques employed in the data analysis; (3) provide for acquiring ground observations and large scale aerial photography; (4) provide the users with the products produced for their evaluation; (5) be responsible for the preparation of the cost benefit analysis, periodical progress reports, and a final report for each test site.

NASA and EROS through their appointed representatives will provide the following support to the project manager.

1. Assist him to meet the goals, objectives and milestones of the detailed plans.
2. Assist in the preparation of budgets, schedules and reports.
3. Provide technical assistance and other support as identified by the project manager.

The primary user of the products produced in this project is the Bureau's resource manager at the district level. In addition information may be aggregated to meet the needs at the State or Washington Office levels. Through consultation with the primary users the data products will be identified, and these products will be checked with the Bureau's Service Center and Washington Office for completeness. This line of communication to the primary user will remain open throughout the life of the project, and the

users will continually be evaluating the products, approving plans, assisting in making ground observations and contributing to the project to assure that it is user driven. Additional Bureau personnel in the Districts and at the Service Center will be called upon to assist in making ground observations, critiquing the products and defining research and development. They will also provide the basic resource expertise needed to ensure the success of the project.

VI. SCHEDULES

Figure VI-1 presents in summary form the principal schedules and milestones anticipated for this project. The table is not intended to be a strict, detailed project schedule and some variations can be anticipated. For example, modifications to the aircraft overflights might be required depending upon local conditions. Similarly, the training schedule might require change in order to get certain key State and District personnel to a course.

Decision points are given for the following dates:

1. September 1976.
2. September 1977.
3. September 1978.
4. July 1979.

The September 1976 through 1978 dates are given as project decision points at which either agency may opt to discontinue the project. These dates overlap with the analysis and evaluation phases upon which such a decision would be made. The July 1979 date is seen as a decision point for the BLM. At that time, the Bureau must decide whether to continue the program operationally and if appropriate (depending upon the option selected) to complete the purchase of the equipment.

PROJECT SCHEDULE AND MILESTONES

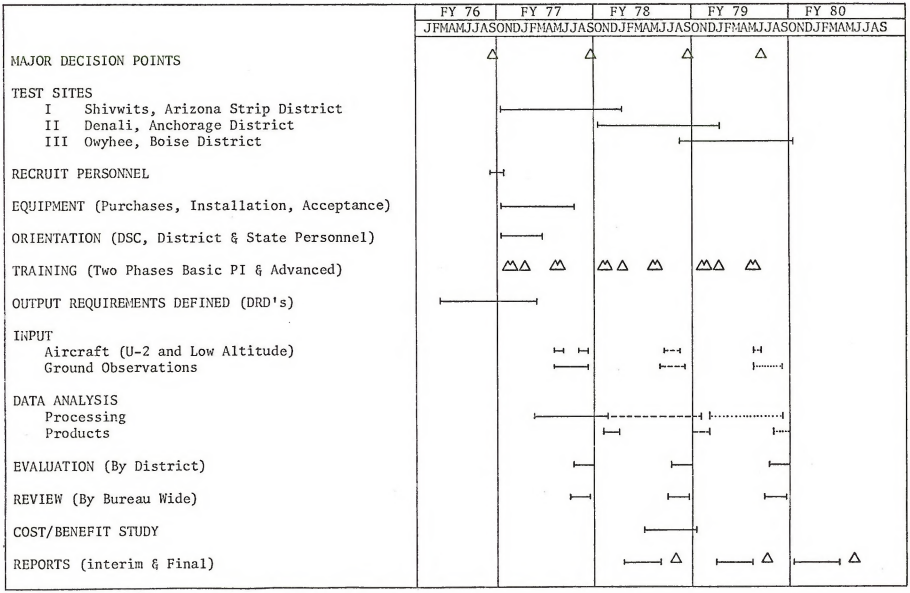


Figure VI - 1

The cost/benefit analysis will be performed by the BLM and will deal with a number of factors besides direct cost benefits. Interim reports on each test site will be prepared and a final project report will provide details on all aspects of the program.

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R. L. Thompson

Appendix: FIRE METEOROLOGY

At the request of the Chief, Division of Fire and Protection Management, BLM, this section on gathering basic fuel hazard vegetative data and fuel hazard information is included as an optional effort to the ASVT if approved. The costs and manpower requirements for this effort are over and above those shown in the body of the detailed project plan. These would have to be identified separately and the task would be conducted as an adjunct effort to the main ASVT.

This effort if approved will take advantage of the fire hazard mapping technique developed in the Susanville project. Fire hazard overlays will be generated to provide fire suppression specialists with current information regarding the fuel hazard of the major communities in the Planning Unit. The procedure will use new and existing data in the form of in place vegetation/cover type maps and ground data collected during the project.

The total resource requirement for instrumenting the Arizona test site with automated meteorological data stations has been estimated and is summarized in Tables I and II. Because of time limitations in preparing this summary, details of the vegetative cover and trees in the test area have not been researched; nor have any attempts been made to review historic weather data for the area. Thus, the number of stations required for providing fire meteorology for the

test area has been estimated based on experience for a similar application in California. It is estimated that 10 stations can adequately sample the area (2 million acres). This corresponds to the 23 stations employed to sample 6.4 million acres in California. It is strongly recommended, however, that a detailed review of the area and of historical information be made prior to committing either to the use of this concept in the test area or to a specific number of stations.

Examination of a topographical map of the area indicates that the test site, located at the northwestern corner of Arizona, included approximately 2 million acres. The test site terrain ranges in elevation from lows of 2,000 feet in the west (Nevada-Arizona boundary), to 6,000 feet (Shivwits Plateau) in the center, to 5,000 feet in the east (Hurricane Cliffs). The Utah-Arizona boundary is the northern test site boundary and the test site stretches approximately 65 miles to the south. The area is characterized by canyons, washes, mountain peaks and the Shivwits Plateau. The highest area in the test site (8,012 feet) is within the Virgin Mountains.

The entire state of Arizona was used as a test site for Orthophoto-quad Mapping in a joint USGS-NASA experiment using U-2 photos. This product is actually a photo of the area and thus will be very useful in providing additional information for the area. But, the cost of acquiring these photo-maps at this time is not justified. The orthophoto quads should be exploited if this project is approved.

In estimating the manpower needs and costs shown in Tables I and II respectively, it was assumed that the stations will be purchased as a turn key system; otherwise, the costs should be adjusted. The costs will be higher if procurement of the DCP's and sensors, and integration, checkout and installation are performed separately. If the integration and checkout and installation are done by either BLM or NASA, or jointly, the out-of-pocket costs could be reduced by approximately 20 percent. Capability to carry out these functions in house will depend on the availability of in house manpower and should be investigated when plans are in the final stages.

Table I summarizes the manpower requirements for conducting this project. The estimates are based on conducting an active program in this area. New methodologies for analyzing and displaying the data will have to be experimented with to gain the full potential of the automated stations. For example, some initial analysis will have to be made to determine the optimum frequency and time of data gathering. Problems of utilizing available computation facilities and data storage will have to be addressed. Therefore, the coordinators on both the BLM and NASA staff must be generally familiar with available facilities in their respective agencies and have the ability to also work with other agencies such as NOAA-NESS.* Preferably the individuals should be versed in project management with

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*National Oceanic and Atmospheric Agency - National Environmental Satellite Service.

broad scientific knowledge. The meteorologist is essential to interpret, utilize, document and evaluate the utility of the data. Maintenance requirements will be dictated primarily by two factors, vandalism and natural causes such as lightning strikes. Both factors at this time are unknown, but with detailed review and analysis of historical data and interviews with residents in the area, a better estimate can be made. Reliability of the DCP and sensors are expected to be quite high.

The total recurring and non-recurring costs are summarized in Table II. These are estimates based on experience gained in the NASA/Ames Research Center - California Division of Forestry joint project on an Automated Fire Weather Data System. Cost ranges are shown for the non-recurring costs because there are so many variables that will affect cost. For example, the time for site preparation and installation of a station can vary markedly depending on terrain and ground condition (wet, dry hard soil, rocky, etc.). The hardware cost variations reflect the price differences expected between vendors, as well as the total number of units procured. The recurring costs are self-explanatory.

TABLE I: MANPOWER REQUIREMENTS

BLM	
Project or Discipline Coordinator	0.5 manyear
Meteorology Specialist	0.5 manyear
Maintenance Technician	1.0 manyear
NASA	
Project or Discipline Coordinator	0.5 manyear
TOTAL MANPOWER	2.5 manyears

TABLE II: AUTOMATED METEOROLOGICAL STATION COST

Non-Recurring

DCP	$ 2.500*	-	4,100
Sensors**	1,400	-	1,800
Conditioning Electronics	700	-	1,000
Power Source (Solar Cells)	1,000	-	1,500
Integration and Checkout	800	-	1,100
Per Unit	$ 6,400	-	9,500
Test site preparation: (Clearing and fencing)			
Labor	$ 150	-	200
Materials (fence posts, etc.)	75	-	100
Per Site	$ 225	-	300
Installation:			
Labor	$ 150	-	200
Materials (mast, guy wire, etc.)	100	-	125
Per Station	$ 250	-	325
Central Data Facility (one required):			
Microprocessor (data formatting)	$ 10,000	-	14,000
TOTAL NON-RECURRING (10) Stations	$78,750	-	115,250

Recurring Cost Per Annum

Replacement Parts	$ 18.000
Maintenance (auto, tools, etc.)	3,000
Computer Terminal and Charges	10,000
Miscellaneous (travel, supplies, etc.)	10,000
TOTAL RECURRING COSTS PER ANNUM	$ 41,000

* Based on new DCP supplier. Quote in lots of 150 units; not certified by NESS at this time.

** Wind speed and direction, temperature, fuel moisture, relative humidity and net solar radiation.

Form 1279-3
(June 1968)

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